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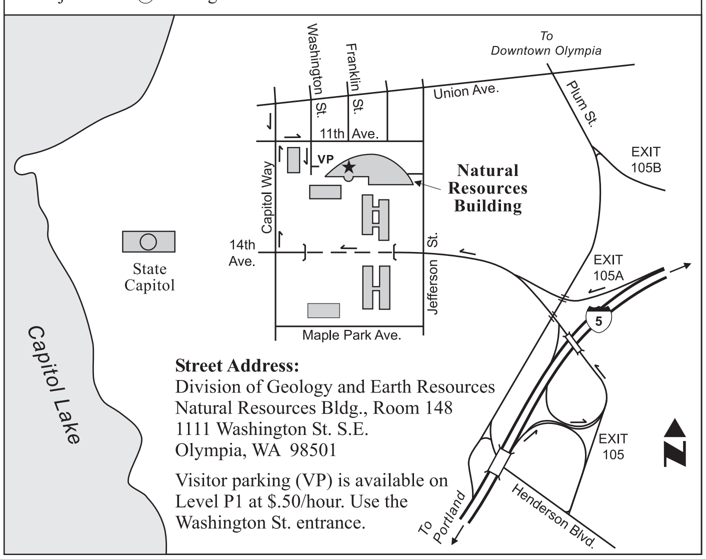

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Division Update

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The Division of Geology and Earth Resources has now published its second Internet-only edition of *Washington Geology*. The first edition generated both positive and negative feedback. Many of our readers were disappointed by the demise of the print version. We certainly sympathize with them, given the substantial history of the printed version. We also received positive feedback from readers who recognize the convenience and cost savings of this type of distribution.

Although in our last issue we offered to print and mail out a paper copy of *Washington Geology* for $3.50, we are no longer able to offer this service, as it defeats the cost savings in staff time and mailing we set out to achieve by using the Internet.

As the Division continues its efforts to adapt to the deteriorating state fiscal situation, we are exploring the use of the Internet for the distribution of many, if not most, of our map products as well. Most new publications will be downloadable from our website for at least 60 days. We will continue to print some geologic maps, but now use a color plotter to provide paper copies of Open File Report maps and some Information Circular maps. These products are also available on CD-ROM. Our current policy is to sell paper copies only if the publication is not available on the web or has plates that must be run on a plotter. Those who don't have a plotter may be able to find one at their local copy shop. Those who don't have a personal computer can usually find one at their local library. Most libraries have Internet access, with printing privileges, available to their patrons. Over the next year, we will be investigating the feasibility of Internet distribution of most of our map products using a map server similar to that currently used by the U.S. Geological Survey. Many copy shops have plotters capable of printing map plates.

These changes present challenges to us in providing information on the geology of Washington to our broad customer base. The capabilities to effectively use the electronic files, both text and map, typically distributed over the Internet vary widely among the general public, other government agencies, and the private-sector professionals. Your patience and feedback are both important to us as we plan and implement these needed changes. ■

Some Division Out-of-Print Items Available

As geological surveys consolidate their holdings, items marked out-of-print in our publications list are often returned to the Division. These will be made available on a first come, first served basis to folks who request them. Availability changes daily, so we cannot post titles on the web. If you are looking for a particular item, call (360) 902-1450 or e-mail geology@wadnr.gov to see if we have it. The item itself will be free, but we will ask you to pay shipping.

Cover Photo: Raymond Foisy of Yakima and Amanda Coleman, Arizona State University graduate student, search for fossils at the Yakima Canyon 'bog' site. Photo taken in May of 2002 by Maria Tcherepova, Arizona State University graduate student. *(See related article on p. 3.)*

Tertiary Flowers, Fruits, and Seeds of Washington State and Adjacent Areas—Part III

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INTRODUCTION

The Tertiary plant fossil record of Washington State and adjacent areas (Fig. 1) spans some 50 million years, from the middle Eocene to the Miocene, and documents plants living in a diverse array of climatic settings (Mustoe, 2001). The oldest Tertiary plant occurrences from Washington are the middle Eocene floras of the Okanogan Highlands in northeastern Washington and adjacent areas of British Columbia. Much of what we know about the radiation of middle Eocene upland temperate groups, including the rose and maple families, comes from this region (Wolfe and Tanai, 1987; Wolfe and Wehr, 1987; Wehr, 1995; Moore and others, 2002). Among the most diverse of these assemblages is the Republic flora, which contains more than 250 types of plant fossils, including beautifully preserved leaves, fruits, and flowers, as well as numerous fossil insects and fish (Wolfe and Wehr, 1987; Wehr, 1995; Wehr and Manchester, 1996). In vivid contrast to the plants of the Okanogan Highlands, the middle Eocene coastal Chuckanut flora (near Bellingham) has many tropical genera, including palms and ferns that are now native to Central America (Pabst, 1968; Mustoe and Gannaway, 1995, 1997).

Younger floras of Oligocene age have an increasingly temperate aspect, with members of the maple, walnut/hickory, and witch hazel families well represented (Meyer and Manchester, 1997). These floras include the Blakeley Formation flora near Seattle and the Gumboot Mountain flora near Mount St. Helens (Mustoe, 2001).

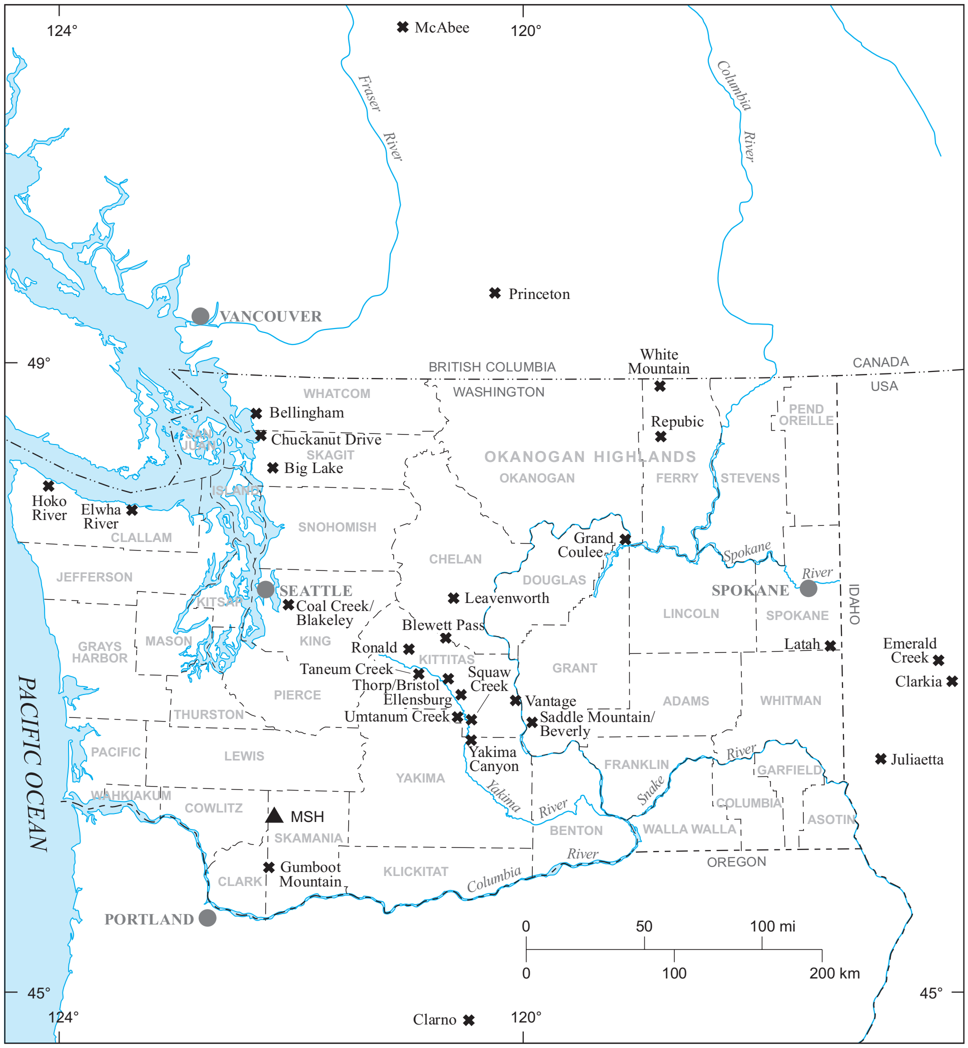


Figure 1. Sites where early Tertiary flowers, fruits, and seeds have been found in the Pacific Northwest. ✖, fossil site; MSH, Mount St. Helens.

In central Washington, middle Miocene floras preserved in sedimentary interbeds within the Columbia River basalts include both Vantage and Yakima Canyon petrified woods (Beck, 1945; Prakash and Barghoorn, 1961a,b; Prakash, 1968; Orsen, 1998; Mustoe, 2001; Pigg and others, 2002) and anatomically preserved 'bog' material at Yakima Canyon *(see cover photo)*, Saddle Mountain, and Squaw Creek. These bog floras preserve permineralized stems, leaves, fruits, cones, and seeds of bald cypress, tupelo gum, sycamore, sweet gum, pine, several types of ferns, oak, grape, and other forms closely related to plants of modern-day temperate woodlands in eastern North America, Asia, and Europe (Miller, 1967, 1982, 1992; Manchester, 1994a; Borgardt and Pigg, 1999; Pigg and Rothwell, 2001; Tcherepova, 2001; Coleman and Pigg, 2002; DeVore and others, 2002a,b; Ickert-Bond and others, 2002; Pigg and others, 2002). Compression floras of the middle Miocene Latah Formation have yielded similar plants at localities in the Spokane area and adjacent western Idaho and at Clarkia and Emerald Creek in central Idaho (Knowlton, 1926; Berry, 1929; Smiley and Rember, 1985).

Most of the plant fossil record in northwestern North America is based on leaves; occurrences of flowers, fruits, and seeds are much rarer. However, these discoveries are very valuable to the Tertiary fossil plant record because details of flowers, fruits, and seeds are the most important features for plant classification and are more diagnostic than leaves alone. Many of the plant occurrences reported here are based on one or only a few specimens, demonstrating that the discovery of each new fossil is exciting and potentially significant.

Plate 1. *(facing page)* **1.** *Toricellia* fruit, UWBM 95238, loc. B4738 (Ronald), x15. **2.** *Palaeocarpinus* fruit, UWBM 97113, loc. B5077 (Republic), x5.7. **3.** Bignoniaceous fruit with seeds, UF 18152-30364, loc. B4131 (Republic), x1.4. **4.** Living *Pteroceltis* fruit, x3.4. **5.** *Corylus* cupulate infructescences containing fruits, SR 98-1-2A, loc. B4131 (Republic), x1.6. **6.** Living fruit and seeds of desert willow, *Chilopsis lineris*, x1.3. **7.** *Cercidiphyllum* seed, UWBM 57084, loc. B4131 (Republic), x5.2. **8.** Living fruit desert willow, *Chilopsis lineris*, x1.3. **9.** *Pteroceltis* fruit, UWBM 96986, loc. A0307B (Republic), x34. **10.** *Celtis* fruit, UWBM 13225-26, loc. A0075 (Beverly), x8.3. **11**, **12.** *Nyssa* endocarp (ventral and dorsal views), UWBM 56469-20, loc. B4101 (Yakima Canyon), x6.6. **13.** *Sloanea* fruit, SR 93-9-9B, loc. B4131 (Republic), x1.4.

This paper documents newly recognized Tertiary occurrences of flowers, fruits, and seeds from significant plant fossil localities in Washington State and adjacent areas, updating this list since the two previous reports (Wehr, 1995; Wehr and Manchester, 1996). It includes a report of the first recognized occurrences of eight families and a total of 20 newly recognized genera since 1996 (Tables 1 and 2). Families are listed in alphabetical order. Specimens are from the following collections: Burke Museum of Natural History and Culture (UWBM), Seattle; Stonerose Interpretive Center (SR), Republic; Western Washington University (WWU), Bellingham; Arizona State University (ASU), Tempe, Arizona; and Florida Museum of Natural History (UF), Gainesville, Florida.

OCCURRENCES BY FAMILY

Araliaceae (Ginseng Family)

Toricellia fruit (Ronald, Kittitas County,
UWBM 95238, loc. B4738, Eocene Roslyn Formation),
Don Hopkins, collector (Plate 1, Fig. 1)

Discussion—Araliaceae is a family of mostly trees, shrubs, and vines that includes the ivies and ginseng. The genus *Toricellia* occurs today from the eastern Himalayas to western China (Mabberley, 1990). Fruits of *Toricellia* are about 2 mm high by 3 mm wide and have three locules, a central one with a germination valve that contains a single seed and two lateral, bladder-like chambers. This genus was previously thought to belong to the Cornaceae (dogwood family), but has recently been reassigned to the Araliaceae (Plunkett and others, 1996). Similar fruits are known from the middle Eocene Clarno nut beds of Oregon as *Tripartisemen bonesii* (Manchester, 1994a, 1999). *Toricellia* fruits are also found in the Eocene Messel flora of Germany and the lower Miocene of Austria. *Toricellia* specimens found in the Eocene Roslyn Formation of Ronald, Washington, are sedimentary casts of the fruit.

Betulaceae (Birch Family)

Palaeocarpinus fruit (Republic, Ferry County,
UWBM 97113, loc. B5077, middle Eocene Klondike
Mountain Formation), Karl and Don Volkman, collectors
(Plate 1, Fig. 2)

Corylus cupulate infructescences containing fruits
(Republic, Ferry County, SR 98-1-2A, loc. B4131,
middle Eocene Klondike Mountain Formation),
Solea Kabakov, collector (Plate 1, Fig. 5)

Discussion—Betulaceae is a family of primarily northern-hemisphere hardwood trees that includes the birches, alders, hop hornbeams, blue ashes, and hazelnuts. The family is divided into two subfamilies, with the birches and alders in one group and the remaining taxa in the other (Zhi-Duan and others, 1999). *Corylus*, the hazelnut or filbert, occurs today in Europe, North America, and eastern Asia and has about a dozen living species. The fruits or nuts are enclosed within prominent husk-like involucres. The currently oldest known fossils assignable to this modern genus are from the middle Eocene flora of Republic (Wehr, 1995; Manchester, 1999). *Palaeocarpinus* is an extinct genus known primarily from Paleocene and some Eocene and Oligocene deposits of western North America, Europe, and China (Crane, 1981; Manchester, 1999; Akhmetiev and Manchester, 2000). It is characterized by two more-or-less-equal bracts that surround a small nutlet. A newly recognized, undescribed species is present in the Republic flora.

Bignoniaceae (Catalpa Family)

Bignoniaceous fruit with seeds (Republic, Ferry County,
UF 18152-30364, loc. B4131, middle Eocene Klondike
Mountain Formation), J. and K. Larson, collectors
(Plate 1, Fig. 3)

Discussion—Bignoniaceae is a family composed mostly of tropical trees, shrubs, and leaning vines that are present today in northern South America and in Asia (Mabberley, 1990). It includes *Catalpa*, trumpet vine (*Campsis*), and desert willow (*Chilopsis*). Fruits in this family are elongate pods that contain numerous small, winged seeds. The fossil record shows the genus *Catalpa* occurring in the Oligocene of North America and Europe (Manchester, 1999), as well as in the Eocene at Republic. The specimen illustrated in Plate 1, Figure 3, shows an elongate pod that is frayed at the tip end and filled with small, winged seeds. An isolated, winged seed is seen at left. A fruit and seeds of the living desert willow (*Chilopsis lineris*) are shown for comparison (Plate 1, Figs. 6 and 8).

Celtidaceae (Hackberry Family)

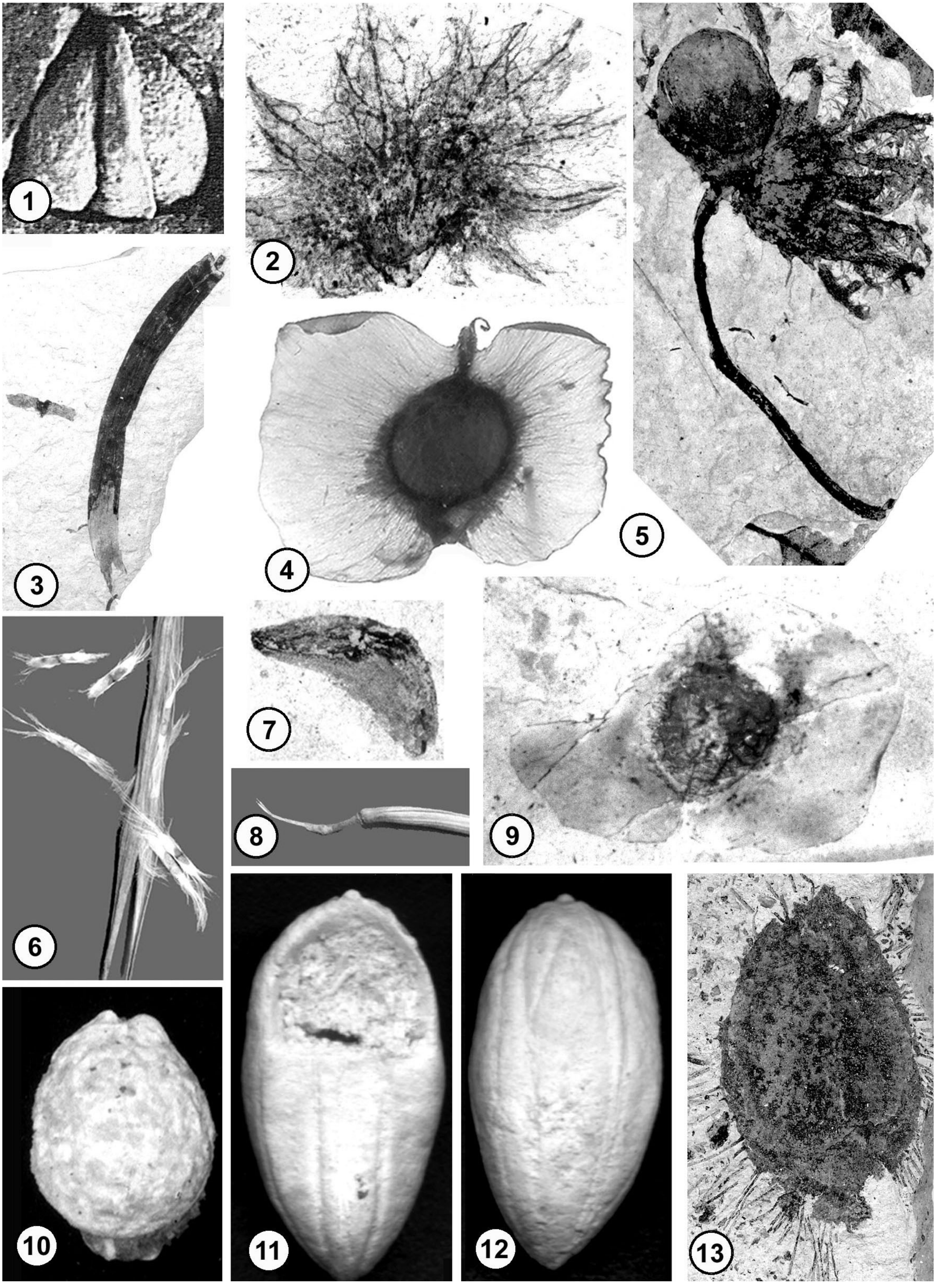
Pteroceltis fruit (Republic, Ferry County,
UWBM 96986, loc. A0307B, middle Eocene Klondike
Mountain Formation), Mary Dunnam, collector
(Plate 1, Fig. 9)

Table 1. Newly recognized families at fossil sites in Washington State and adjacent areas, described from flowers, fruits, and seeds

Family	Genera	Age
Araliaceae	*Toricellia*	Eocene
Elaeocarpaceae	*Sloanea*	Eocene
Hydrangeaceae	*Hydrangea*	Eocene
Lythraceae	Lythraceous fruit	Miocene
Menispermaceae	*Odontocaryoidea*	Eocene
Rhamnaceae	*Paliurus*, Rhamnaceous fruit	Miocene
Symplocaceae	*Symplocus*	Eocene
Trapaceae	*Trapa*	Miocene

Table 2. Newly recognized genera from families previously known at fossil sites in Washington State and adjacent areas, described from flowers, fruits, and seeds

Family	Genera	Age
Celtidaceae	*Pteroceltis* *Celtis*	Eocene Miocene
Cornaceae	*Cornus, Nyssa, Mastixicarpum*	Miocene
Fagaceae	*Fagus* *Quercus*	Eocene Miocene
Hamamelidaceae	*Exbucklandia*	Oligocene
Juglandaceae	*Platycarya* *Pterocarya*	Eocene Oligocene
Sapindaceae	*Dipteronia*	Eocene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Celtis fruit (Beverly, Grant County, UWBM 13225-26, loc. A0075, Miocene Ellensburg Formation), W. N. Lavall, collector (Plate 1, Fig. 10)

Discussion—The family Celtidaceae (hackberry family) is now recognized as distinct from the elms (Ulmaceae) to which this group is closely related (Judd and others, 2002). The Asian genus *Pteroceltis*, known from China and Mongolia, has a fruit with a distinctive wing (Plate 1, Figs. 4 and 9), which has just been found in the middle Eocene Republic flora. Hackberry (*Celtis*) fruits are present in the Selah interbed of the Ellensburg Formation at Beverly (Plate 1, Fig. 10).

Cercidiphyllaceae (Katsura Family)

Cercidiphyllum seed (Republic, Ferry County, UWBM 57084, loc. B4131, middle Eocene Klondike Mountain Formation), Jerry Hooker, collector (Plate 1, Fig. 7)

Discussion—The family Cercidiphyllaceae is now known only from two species of the genus *Cercidiphyllum*, the katsura tree. These plants are trees or shrubs native to Japan and China (Mabberley, 1990). Members of this family were widespread in the northern hemisphere high- and mid-latitude floras in the Late Cretaceous and Tertiary (Crane and Stockey, 1985). The tiny seeds in the Republic flora are shaped like boomerangs.

Cornacaeae (Dogwood Family)

Nyssa endocarp (Yakima Canyon, Yakima County, UWBM 56469-20, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 1, Figs. 11 and 12)

Discussion—The family Cornacaeae includes plants of both temperate (*Cornus*, dogwood; *Nyssa*, tupelo gum) and tropical occurrence (for example, *Mastixia* and *Diplopanax* [Mai, 1993; Tiffney and Haggard, 1996; Stockey and others, 1998]). (Some authors place *Nyssa*, along with several other genera, in the family Nyssaceae.) Dogwoods and their relatives are represented extensively in the fossil record by both leaves and endocarps (fruit stones), which have a characteristic type of germination valve from which the young seedling emerges (Manchester, 1994a; Eyde, 1997; Manchester and others, 1999). Today *Nyssa* is a plant common to swampy areas of the southeastern U.S. and China. Both fossil *Nyssa* endocarps and petrified *Nyssa* wood are common in the Yakima Canyon flora, which also contains bald cypress and fern species similar to those growing in swampy conditions today (Beck, 1945; Prakash and Barghoorn, 1961b; Prakash, 1968; Pigg and Rothwell, 2001; Tcherepova, 2001).

Elaeocarpaceae

Sloanea fruit (Republic, Ferry County, SR 93-9-9B, loc. B4131, middle Eocene Klondike Mountain Formation), Doug Scott and Wayne Phillips, collectors (Plate 1, Fig. 13)

Discussion—The family Elaeocarpaceae contains 12 genera and about 350 species of tropical and subtropical trees and shrubs. They grow today in eastern Asia, Indomalaysia, Australasia, the Pacific area, Madagascar, South America, and the West Indies (Heywood, 1993). *Sloanea*, the second largest genus in the family, contains about 120 species. The fruit has a spiny surface and splits into four to five elongate valves when mature. Fossil fruits of *Sloanea* are known widely in the Paleocene of western North America and Greenland and extend into the Eocene of western North America (Brown, 1962; Manchester, 1999). In Washington State, they have been found in Eocene rocks near Blewett Pass and Chuckanut Drive (near Bellingham) and in the Republic flora.

Fagaceae (Oak Family)

Fagus cupule (McAbee, British Columbia, UWBM 74334ab, loc. B5751, middle Eocene Kamloops Group), W. C. Wehr, collector (Plate 2, Fig. 14)

Fagus fruit (Republic, Ferry County, UWBM 39206, loc. B4131, middle Eocene Klondike Mountain Formation), Lisa Barksdale, collector (Plate 2, Fig. 15)

Quercus hiholensis acorn (Yakima Canyon, Yakima County, UWBM 56470-3, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 2, Fig. 16)

Quercus hiholensis acorn (Yakima Canyon, Yakima County, UWBM 55126, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 2, Fig. 17)

Quercus acorn (Thorp/Bristol, Kittitas County, UWBM 57492, loc. B4972, Miocene Ellensburg Formation), Don Hopkins, collector (Plate 2, Fig. 20)

Fagopsis undulata fruit (White Mountain, Ferry County, UWBM 74316, loc. B5079, Eocene Klondike Mountain Formation), W. C. Wehr, collector (Plate 2, Fig. 21)

Discussion—The Fagaceae or oak family includes the oaks, beeches, chestnuts, and several related genera. With the exception of the southern hemisphere genus *Nothofagus*, which many authors now recognize in its own family, Fagaceae is a northern hemisphere family of trees and shrubs that has an extensive fossil record (Crepet, 1989; Manchester, 1999). Before material figured in the present paper was discovered, *Fagus* cupules were known only back to the Oligocene in western North America (Meyer and Manchester, 1997) and extensively in the Neogene in Europe (Denk and Meller, 2001). Older beech (*Fagus*) nuts and cupules are now recognized in the middle Eocene Republic and McAbee floras. They are compared with extant examples (Plate 2, Figs. 14, 15, 18, and 19). Acorns (*Quercus*) are first known from the middle Eocene Clarno nut beds (Manchester, 1994a). They occur in many compression floras, such as the Miocene Thorp/Bristol flora in Kittitas County. Rare permineralized white oak acorns showing internal anatomical structure, developmental features, cynipid wasp galls, and fungi are known from the middle Miocene Yakima Canyon flora (Borgardt and Pigg, 1999; DeVore and others, 2002b), where white oak wood has recently been confirmed (Pigg and others, 2002). Fruits and seeds of an unusual extinct genus, *Fagopsis*, originally described from the Florissant flora of Colorado (Hollick, 1909; Manchester and Crane, 1983), are present in the Eocene floras at Resner Canyon and White Mountain, in Ferry County near Republic.

Hamamelidaceae (Witch Hazel Family)

Liquidambar infructescence (Yakima Canyon, Yakima County, UWBM 40 (90), loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 2, Fig. 22)

Liquidambar infructescence (Yakima Canyon, Yakima County, UWBM 95A16 #5, loc. B4101, middle Miocene

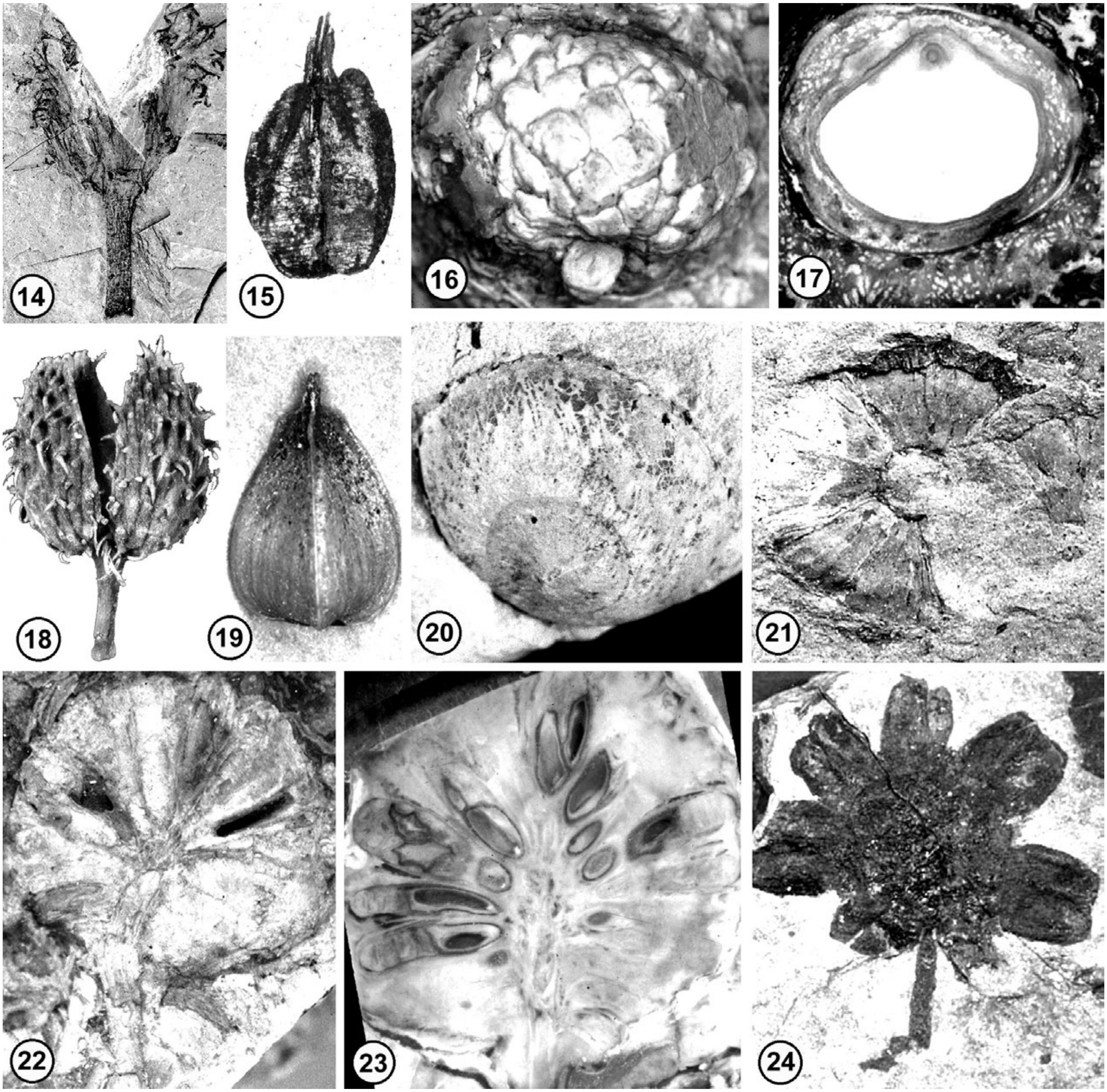


Plate 2. **14.** *Fagus* cupule, UWBM 74334ab, loc. B5751 (McAbee, BC), x2. **15.** *Fagus* fruit, UWBM 39206, loc. B4131 (Republic), x3.8. **16.** *Quercus hiholensis* acorn, UWBM 56470-3, loc. B4101 (Yakima Canyon), x4.5. **17.** *Quercus hiholensis* acorn (cross section), UWBM 55126, loc. B4101 (Yakima Canyon), x5.3. **18.** Living *Fagus* cupule, for comparison, x2.5. **19.** Living *Fagus* fruit, for comparison, x3.5. **20.** *Quercus* acorn, UWBM 57492, loc. B4972 (Thorp/Bristol), x2.6. **21.** *Fagopsis undulata* fruit, UWBM 74316, loc. B5079 (White Mountain), x4. **22.** *Liquidambar* infructescence, UWBM 40 (90), loc. B4101 (Yakima Canyon), x2.9. **23.** *Liquidambar* infructescence, UWBM 95A16 #5, loc. B4101 (Yakima Canyon), x4. **24.** *Exbucklandia* infructescence, UWBM 95378AB, loc. B5570 (Gumboot Mountain), x2.1.

Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 2, Fig. 23)

Exbucklandia infructescence (Gumboot Mountain, Skamania County, UWBM 95378AB, loc. B5570, Oligocene unnamed unit), Jim Goedert, collector (Plate 2, Fig. 24)

Discussion—The family Hamamelidaceae traditionally includes the witch hazels (*Hamamelis*), sweet gum (*Liquidambar*), and other related woody trees and shrubs of warm temperate or subtropical habitats (Heywood, 1993). Many current authors subdivide this family into separate families (Endress, 1989). *Liquidambar*, the sweet gum, placed by many in the family Altingiaceae, is represented today by about five species that have a disjunct distribution, occurring in western and eastern Asia, Central America, Mexico, and eastern North America (Ferguson, 1989; Shi and others, 2001). *Liquidambar* fruits are often found in association with leaves at many Tertiary localities such as the middle Miocene Clarkia and Emerald Creek sites in central Idaho (Smiley and Rember, 1985), but compressed fossil fruits provide little detail for study. Anatomically preserved fruits are known from the middle Miocene of Denmark and Yakima Canyon, Washington (Ickert-Bond and others, 2002). Fossil wood of this genus has been reported from the Umtanum Creek horizon of Yakima Canyon and at Vantage (Beck, 1945; Prakash and Barghoorn, 1961a; Prakash, 1968; Pigg and others, 2002). Isolated *Liquidambar* seeds have been documented along with leaves in the middle Eocene Republic flora (Wehr, 1995). The Asian genus *Corylopsis* (winter hazel), known from seeds found at Eocene and younger localities in Europe and Eocene localities in eastern North America (Manchester, 1999), was recognized on the basis of leaves for the first time in the Republic flora (Radtke and others, 2001). Leaves and fruits resembling the Chinese endemic genus *Exbucklandia* have been described from the Miocene in Idaho and Washington (Brown, 1946), as well as the Oligocene of Oregon (Lakhanpal, 1958). They are known from the Oligocene Gumboot Mountain locality (W. C. Wehr, unpub. data).

Hydrangeaceae (Hydrangea Family)

Hydrangea flower (Chuckanut Drive, Skagit County, WWU-02-2-7, loc. WWU-CD5, late Paleocene(?) Chuckanut Formation), Harold Crook, collector (Plate 3, Fig. 25)

Discussion—Hydrangeaceae is a family occurring today in Asia, eastern North America, and northern South America. It includes the ornamental shrubs of the genus *Hydrangea*. Fossil remains include both the large persistent sterile flowers, like those in living shrubs, and rare fossil fruits, such as permineralized forms from the Clarno Formation (Manchester, 1994a). They are well represented from the Eocene on into the late Tertiary in Europe and North America and in the Miocene in Asia (Manchester, 1999).

Icacinaceae (Moonvine Family)

Palaeophytocrene fruit (Ronald, Kittitas County, UWBM 96991, loc. B4378, Eocene Roslyn Formation), Lori and Rob Healy, collectors (Plate 3, Fig. 26)

Iodes fruit (Big Lake, Skagit County, UWBM 96972, loc. A3171, late Eocene Chuckanut Formation), Jon Hager, collector (Plate 3, Fig. 27)

Discussion—The family Icacinaceae occurs today in the tropics of Africa, Asia, and South America (Heywood, 1993), but it is well represented by genera including *Palaeophytocrene* and *Iodes* in the Tertiary London Clay in Europe and in the middle Eocene Clarno nut beds of Oregon and other sites in North America (Reid and Chandler, 1933; Collinson, 1983; Crane and others, 1990; Manchester, 1994a, 1999; Kvaček and Buzek, 1995). The fruit stones (endocarps) of these genera vary in shape from ellipsoidal to rounded and are characterized by conspicuous pits on their surfaces. *Palaeophytocrene* and *Iodes* have been found at Eocene localities at Chuckanut, Big Lake, Ronald, Blewett Pass, Leavenworth (Eagle Creek), Hoko River, Elwha River, and Republic in Washington.

Juglandaceae (Walnut Family)

Pterocarya fruit (Gumboot Mountain, Skamania County, UWBM 77554A, loc. B5570, Oligocene unnamed unit) Jim Goedert, collector (Plate 3, Fig. 28)

Platycarya fruit (Ronald, Kittitas County, UWBM 93343, loc. B4378, Eocene Roslyn Formation), Don Hopkins, collector (Plate 3, Fig. 29)

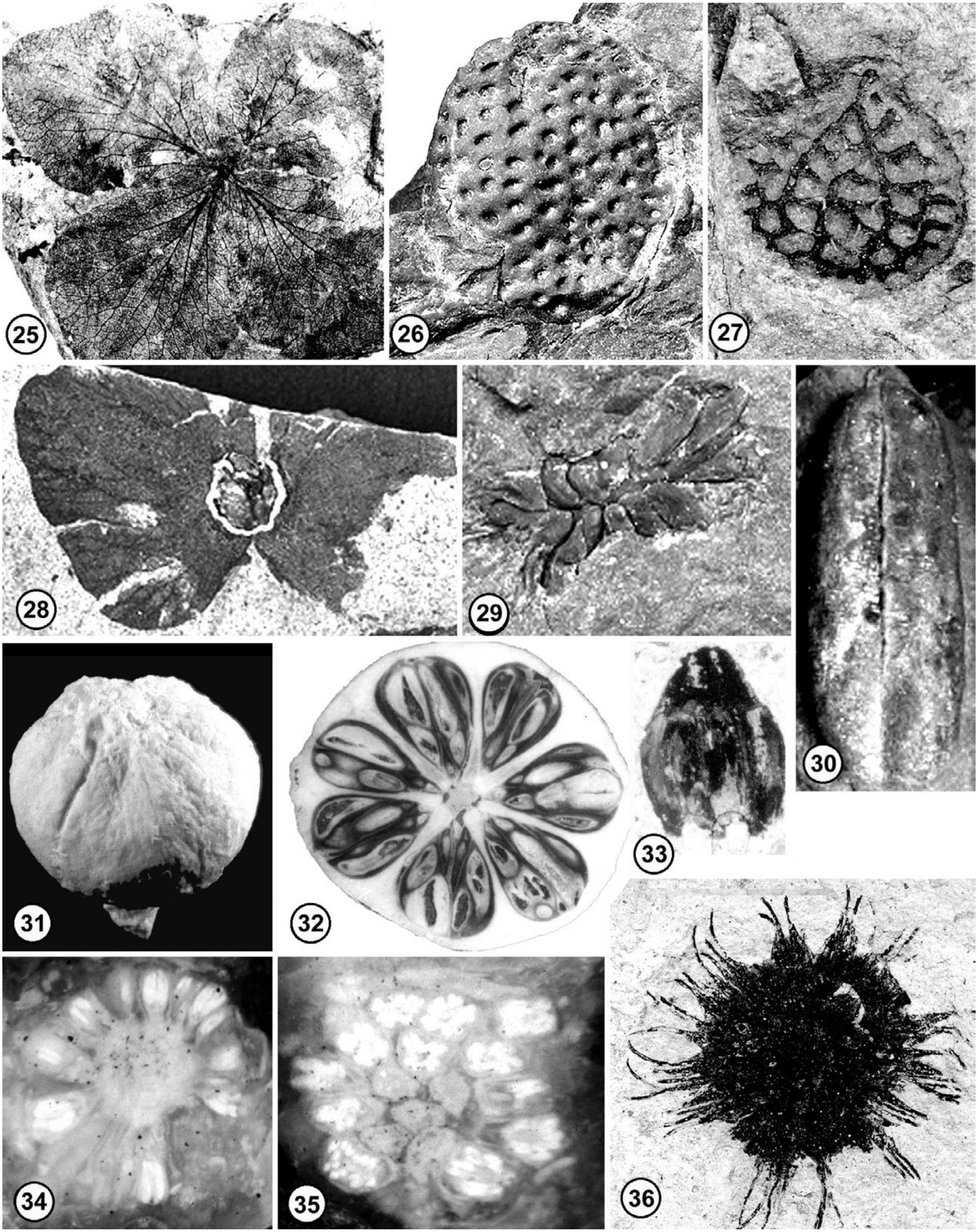
Discussion—The walnut family, Juglandaceae, includes the well-known modern genera *Juglans* (walnut) and *Carya* (hickory), as well as a number of living Asian forms. The evolutionary history of this family includes fossil records of both living and extinct genera and has been reviewed in detail by Manchester (Manchester and Dilcher, 1982; Manchester, 1987, 1994a, 1999). *Pterocarya* and *Platycarya* are two winged forms with restricted distributions today: *Pterocarya* occurs in the Caucasus region of Europe and Asia and *Platycarya* occurs only in Asia. They have been found extensively in the Tertiary in Europe, Asia, and North America (Manchester, 1999). *Ptererocarya* is present at the Oligocene Gumboot Mountain locality and *Platycarya* at the Eocene locality at Ronald.

Lythraceae (Loosestrife Family)

Lythraceous fruit (Yakima Canyon, Yakima County, UWBM 55134, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 3, Figs. 31 and 32)

Discussion—The best known modern members of the Lythraceae or loosestrife family are the purple loosestrife, an invader of aquatic habitats, and *Lagerstroemia*, the ornamental crepe myrtle (Graham, 1964; Graham and others, 1993). The family has a well-established fossil record (Graham and Graham, 1971; Tiffney, 1981; Cevallos-Ferriz and Stockey, 1988). The genus *Decodon* is the most common fossil genus and can be recognized from its capsule-like fruits and distinctive pyramid-shaped seeds. Fruits and seeds of *Decodon* and related genera are known from the London Clay, many other Tertiary European and Russian sites, and the Brandon lignite of Vermont (Reid and Chandler, 1933; Dorofeev, 1963; Tiffney, 1981). Permineralized *Decodon* seeds occur in the middle Eocene Clarno nut beds of Oregon and Princeton chert of British Columbia (Manchester, 1994a; Cevallos-Ferriz and Stockey, 1988), the middle Miocene of Nevada (Bertram, 1998), and the middle Miocene of Hokkaido, Japan (Matsumoto and others, 1997). Vegetative remains have been found in the Princeton chert (Little and Stockey, 2000), and a whole-plant reconstruction based on compressed Miocene remains has recently been described from the Czech Republic (Kvaček and Sakala, 1999). Anatomically preserved flowers, fruits, and pollen (*Enigmocarpon*) from the Deccan Intertrappans of India may also have lythraceous affinity (Sahni, 1943; Mahabale and Deshpande, 1959). The middle Miocene Yakima Canyon site contains a distinctive, permineralized fruit currently under study that resembles the modern crepe myrtle *Lagerstroemia* and the closely related Indian mangrove plant *Sonneratia* (Mahabale and Deshpande, 1959; DeVore and others, 2002a).

Plate 3. *(facing page)* **25.** *Hydrangea* flower, WWU-02-2-7, loc. WWU-CD5 (Chuckanut Drive), x1.3. **26.** *Palaeophytocrene* fruit, UWBM 96991, loc. B4378 (Ronald), x4.2. **27.** *Iodes* fruit, UWBM 96972, loc. A3171 (Big Lake), x4.2. **28.** *Pterocarya* fruit, UWBM 77554A, loc. B5570 (Gumboot Mountain), x3.8. **29.** *Platycarya* fruit, UWBM 93343, loc. B4378 (Ronald), x3.8. **30.** *Odontocaryoidea* fruit, UWBM 56811, loc. B4378, x3.7. **31, 32.** Lythraceous fruit, UWBM 55134, loc. B4101 (Yakima Canyon), external side view prior to sectioning (x4.7) and cross section (x5.7), respectively. **33.** Platanaceous stamen cluster, UWBM 73520, loc. B4131 (Republic), x8.9. **34, 35.** Platanaceous staminate inflorescence, ASUYC, loc. B4101 (Yakima Canyon), x16.8 and x17.8, respectively. **36.** Platanaceous pistillate inflorescence, UWBM 93520AB, loc. B2737 (Republic), x2.4.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Menispermaceae (Moonseed Family)

Odontocaryoidea fruit (Ronald, Kittitas County, UWBM 56811, loc. B4378, Eocene Roslyn Formation), Don Hopkins, collector (Plate 3, Fig. 30)

Discussion—The Menispermaceae or moonseed family includes about 78 living genera and 520 species and consists mostly of tropical woody climbers (Heywood, 1993). Today this family is known in Asia, Africa, Australia, and America. Menisperm fossil fruits are well known from the London Clay and the Clarno nut beds (Reid and Chandler, 1933; Collinson, 1983; Crane and others, 1990; Manchester, 1994a).

Platanaceae (Sycamore Family)

Platanaceous stamen cluster (Republic, Ferry County, UWBM 73520, loc. B4131, middle Eocene Klondike Mountain Formation), Jon Hager, collector (Plate 3, Fig. 33)

Platanaceous staminate inflorescences (Yakima Canyon, Yakima County, ASUYC, loc. B4101, middle Miocene Ellensburg Formation), K. B. Pigg, collector (Plate 3, Figs. 34 and 35)

Platanaceous pistillate inflorescence (Republic, Ferry County, UWBM 93520AB, loc. B2737, middle Eocene Klondike Mountain Formation), Keith Nannery and Bonnie Blackstock, collectors (Plate 3, Fig. 36)

Discussion—Members of the sycamore family have an extensive fossil record that shows they were already widely distributed by the middle Cretaceous (Friis and others, 1988; Magallón-Puebla and others, 1997). Sycamores or plane trees were quite diverse in the higher- and mid-latitude Paleocene and Eocene floras of Europe, North America, and the Kamchatka peninsula of northeastern Siberia (Bundantsev, 1996) and included plants bearing compound leaves (*Platanites*), the distinctive digitately lobed *Macginitiea*, and leaf forms quite similar to modern relatives (for example, *Platanus nobilis*) (Manchester, 1986; Wolfe and Wehr, 1987; Crane and others, 1988, 1990; Pigg and Stockey, 1991; Kvaček and others, 2001). Many of these leaf compressions are accompanied by the spherical fruit-bearing and pollen-bearing heads, which can be assigned to *Macginicarpa* and *Platananthus*, respectively. Permineralized versions of *Macginicarpa* are known in association with *Macginitiea* leaves and pollen-bearing *Platananthus* heads and platanaceous wood in the Eocene Clarno Formation, where they represent the "Clarno plane tree" (Manchester, 1986). Platanaceous fruiting heads and isolated stamen clusters are known from the middle Eocene Republic flora and the Oligocene Blakeley flora, and tiny platanaceous pollen-bearing heads have been recognized in the middle Miocene Yakima Canyon flora along with wood at Vantage (Prakash and Barghoorn, 1961a; Prakash, 1968; Pigg and others, 2002).

Rhamnaceae (Buckthorn Family)

Paliurus fruit (Grand Coulee, Douglas County, UWBM 56386, loc. A6621, Miocene Ellensburg Formation), V. S. Mallory, collector (Plate 4, Fig. 37)

Rhamnaceous fruit (Yakima Canyon, Yakima County, UWBM 95-21A, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 4, Fig. 38)

Rhamnaceous fruit (Yakima Canyon, Yakima County, ASUYC 100, loc. B4101, middle Miocene Ellensburg Formation), K. B. Pigg, collector (Plate 4, Fig. 39)

Discussion—Rhamnaceae is a relatively large family today that includes plants of cosmopolitan distribution (Heywood, 1993). The fossil record of this group includes leaves of several genera, including *Rhamnus* and *Ziziphus*. The best known fruits are of *Paliurus*, a genus that today has only about five species, one native to southern Europe and western Asia and the others occurring in China and southeast Asia (Richardson and others, 2000a,b; Tcherepova, 2001). The modern *Paliurus* from Europe and western Asia, *Paliurus spina-christi,* is sometimes called the crown of thorns, as its highly thorny stems are thought to have been used to form Christ's crown. *Ziziphus* is a large cosmopolitan genus that includes a number of shrubs adapted to dry and harsh conditions. While *Paliurus* and *Ziziphus* are closely related as members of a basal tribe of the Rhamnaceae and have similar drupe-like fruits and characteristic dehiscence valves, *Paliurus* endocarps possess a distinctive skirt or flange that is not developed in *Ziziphus* (Richardson and others, 2000a,b; Tcherepova, 2001). *Paliurus* fruits also possess a nectiferous disc. Fruits of this genus are known in the Eocene and Miocene of North America and Asia and the Oligocene and Miocene of Europe; they persist today only in Asia and southern Europe (Manchester, 1999). In Washington State, *Paliurus* endocarps occur in the Latah Formation near Spokane. A permineralized rhamnaceous fruit of close affinities to *Paliurus* and *Ziziphus* is known from the middle Miocene Yakima Canyon flora (Tcherepova, 2001).

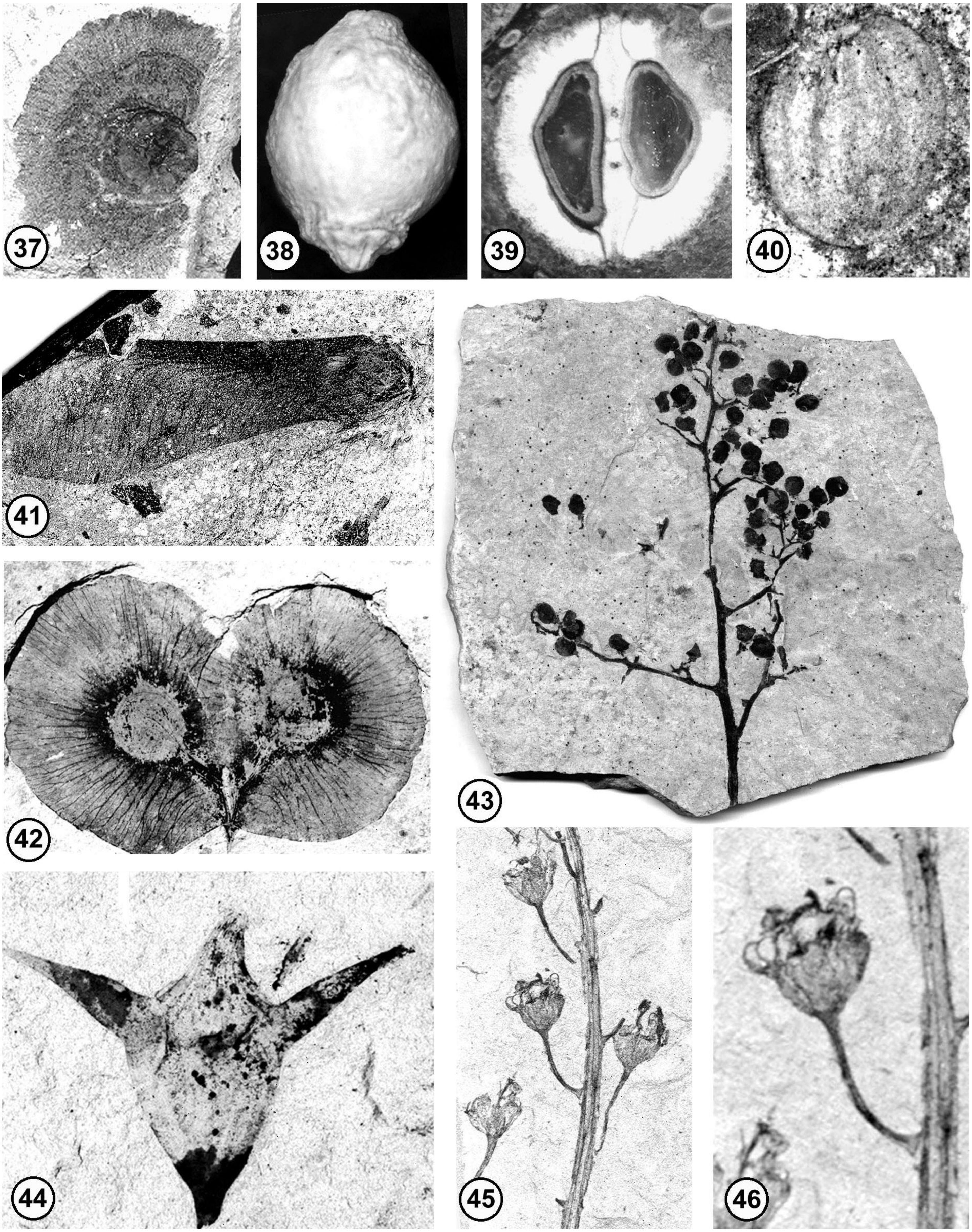
Sapindaceae (Soapberry Family)

Dipteronia two-carpellate fruit (Republic, Ferry County, SR 92-20-3A, loc. B4131, middle Eocene Klondike Mountain Formation), Marion Dammann, collector (Plate 4, Fig. 42)

Acer fruit (Gumboot Mountain, Skamania County, UWBM 97675, loc. B5570, early Oligocene unnamed unit), Jim Goedert, collector (Plate 4, Fig. 41)

Discussion—Sapindaceae is a large family of trees and shrubs widely distributed in the tropics and warm regions of the world (Heywood, 1993; Manchester, 1999; McClain and Manchester, 2001). Two genera in this family that have excellent fossil records are *Dipteronia* and *Acer* (the maple genus). *Dipteronia* is known today only from two species in China, whereas *Acer* is widely distributed throughout the northern hemisphere. These two genera have long been recognized as sister taxa and were previously placed in their own family, the Aceraceae. Recent phylogenetic analyses have recognized their relationship as a clade within the family Sapindaceae (McClain and Manchester, 2001). Living examples of the genus *Dipteronia* encompasses both two- and three-winged fruits. An early discovered fossil example of this fruit was initially assigned to the ex-

Plate 4. *(facing page)* **37.** *Paliurus* fruit, UWBM 56386, loc. A6621 (Grand Coulee), x4.1. **38.** Rhamnaceous fruit, UWBM 95-21A, loc. B4101 (Yakima Canyon), x9.5. **39.** Rhamnaceous fruit, ASUYC 100, loc. B4101 (Yakima Canyon), x7.1. **40.** *Symplocus* fruit, UWBM 93529, loc. B6202b (Taneum Creek), x4.5. **41.** *Acer* fruit, UWBM 97675, loc. B5570 (Gumboot Mountain), x1.3. **42.** *Dipteronia* fruit, SR 92-20-3A, loc. B4131 (Republic), x3.2. **43.** cf. *Tilia* fruits on branch, SR 01-01-07, loc. B4131 (Republic), x0.8. **44.** *Trapa* fruit, UWBM 57296A, loc. B5493 (Juliaetta), x4.3. **45.** *Trochodendron* infructescence, SR 00-01-02, loc. B4131 (Republic), x3.3. **46.** Detail of Fig. 45, x7.3.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tinct genus *Bohlenia*, based on a single three-carpellate specimen (Wolfe and Wehr, 1987), but further collecting showed fossil remains can be either two- or three-carpellate. This is a good example of the dangers of identifying a fossil from a limited sample of material when one is unaware of the full range of variation in both the fossil and extant forms.

The maple genus, *Acer,* is widespread today in Asia, North America, and Europe (Manchester, 1999). Maples have paired, winged fruits (samaras) that separate before dispersing. Western North American occurrences of *Acer* fossil fruits and leaves are diverse with more than 91 species described (Wolfe and Tanai, 1987). The oldest confirmed occurrence of true maples is in the Paleogene of Alaska (Wolfe and Tanai, 1987), although samaras that may be assignable to *Acer* are found in the late Paleocene of North Dakota (Crane and others, 1990). The fossil record suggests that after appearing in North America in the Paleocene, maples took a Beringial crossing to Asia in the Eocene and arrived in Europe by the Oligocene (Manchester, 1999). The Gumboot Mountain specimens are early Oligocene.

Symplocaceae

Symplocus fruit (Taneum Creek, Kittitas County, UWBM 93529, loc. B6202b, Eocene Naches Formation), Don Hopkins, collector (Plate 4, Fig. 40)

Discussion—*Symplocus* was formerly considered a member of the family Theaceae (tea, camellias). It is now placed in a family of its own that contains two genera and about 500 species occurring in tropical and subtropical areas of the Old and New World (Mabberley, 1990). This genus is well known in the Tertiary of Europe, the Eocene and Miocene of eastern North America, and, in western North America, in the Eocene of Oregon and California (Manchester, 1994a, 1999; Tiffney and Haggard, 1996). During the Pliocene, it apparently extended its distribution into Japan and areas of present-day occupation in the Caribbean, South America, and the South Pacific. It is now known in the Eocene of Washington.

Tiliaceae (Linden Family)

cf. *Tilia* fruits on branch (Republic, Ferry County, SR 01-01-07, loc. B4131, middle Eocene Klondike Mountain Formation), John Rhodes, collector (Plate 4, Fig. 43)

Discussion—The Tiliaceae or linden family traditionally includes temperate and tropical trees and shrubs of cosmopolitan distribution (Mabberley, 1990). Recent authors have merged this family with the closely related Malvaceae (cotton family), Bombacaceae (kapok family), and Sterculiaceae (chocolate family)(Manchester, 1999). The genus *Tilia* is a tree known today in woodlands of eastern North America, Europe, and Asia that is frequently planted as an ornamental in the temperate areas of the U.S. and Europe. It is the tree along the famous boulevard 'Unter den Linden' that leads up to the Brandenburg Gate in Berlin, Germany. The fossil record of *Tilia* is well documented, based in particular on the distinctive bracts that subtend the fruits. Differences in the bract shape correlate with patterns of migration of lindens from North America into areas of Asia and Europe throughout the Tertiary (Manchester, 1994b, 1999).

Trapaceae (Water Chestnut Family)

Trapa fruit (Juliaetta, Latah County, Idaho, UWBM 57296A, loc. B5493, Miocene Latah Formation), Judy Potter and Arthur Cridland, collectors (Plate 4, Fig. 44)

Discussion—Trapaceae is a monotypic family based on the genus *Trapa*, the water chestnut. These plants are floating aquatic plants that produce a hard, spiny fruit. Today 15 species are found in central and southeastern Europe, Asia, and Africa, but not in North America. The earliest fossil record of *Trapa*-like fruits is in the Maastrichtian (Upper Cretaceous) of Russia (Golovneva, 1991). *Trapa* fruits occur in several floras of western North America, including the late Oligocene Weaverville flora of California, the Miocene Latah Formation of Idaho, and the Miocene Stinking Water flora of Oregon (Manchester, 1999). They are widespread in the Miocene of Europe and also present in the Pliocene Citronelle flora of Alabama. The pollen record for *Trapa* includes the late Miocene Brandywine pollen flora of southern Maryland (Graham, 1999). *Trapa* fruits from the Latah Formation near Juliaetta, Idaho, are somewhat triangular in outline and have several large spines on their outer surface.

Trochodendraceae

Trochodendron infructescence (Republic, Ferry County, SR 00-01-02, loc. B4131, middle Eocene Klondike Mountain Formation), Thodd Shearer, collector (Plate 4, Figs. 45 and 46)

Discussion—*Trochodendron*-like leaves are common in Tertiary floras; however they cannot be identified with certainty without reproductive structures. The Republic leaves (Wolfe, 1989) are associated with the characteristic fruits, which helps confirm their assignment. An extinct member of the family, *Nordenskioldia*, is well known in high- to mid-latitude northern hemisphere floras from the Cretaceous to the Miocene (Crane and others, 1990, 1991; Manchester and others, 1991; Pigg and others, 2001). A newly described species of *Trochodendron* from Republic, *Trochodendron nastae*, occurs with closely associated fruits (Pigg and others, 2001).

Ulmaceae (Elm Family)

Ulmus fruit (Latah, Spokane County, UWBM 29112, loc. A7672, Miocene Latah Formation), V. S. Mallory, collector (Plate 5, Fig. 47)

Ulmus fruits on branching infructescence (Republic, Ferry County, UWBM 77433, loc. B4131, middle Eocene Klondike Mountain Formation), W. C. Wehr, collector (Plate 5, Fig. 49)

Discussion—The Ulmaceae or elm family includes trees and shrubs distributed in both the northern and southern hemispheres (Manchester, 1989). Fossil *Ulmus* (elm) fruits from the middle Eocene Republic flora and Miocene Latah Formation greatly resemble their living counterparts (Plate 5, Fig. 48).

Vitaceae (Grape Family)

Vitaceous endocarp (Umtanum Creek, Kittitas County, UWBM 4770, loc. 2989, middle Miocene Ellensburg Formation), W. C. Wehr, collector (Plate 5, Fig. 50)

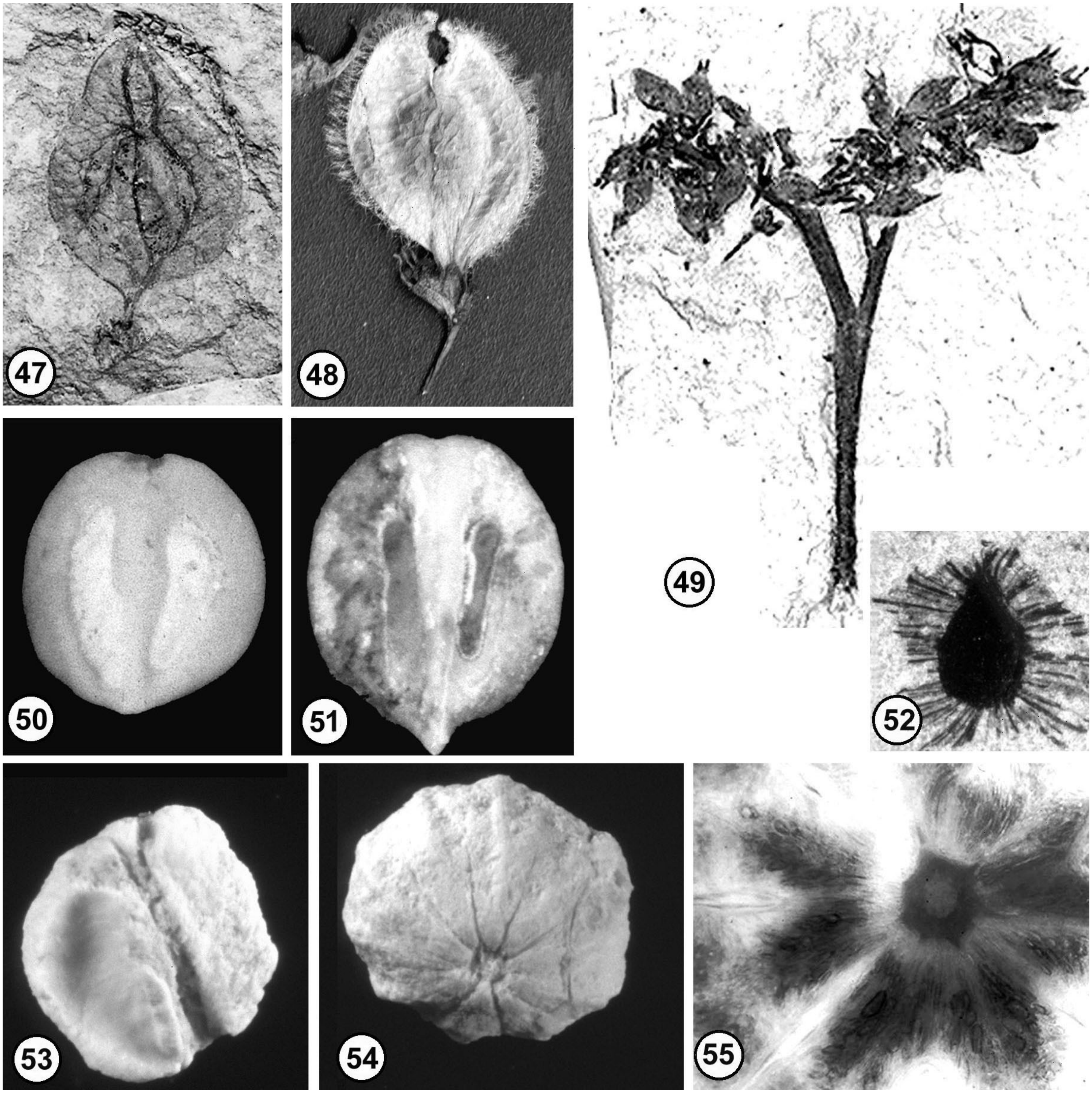

Plate 5. **47.** *Ulmus* fruit, UWBM 29112, loc. A7672 (Latah), x3.8. **48.** Modern *Ulmus* fruit for comparison, x5.1. **49.** *Ulmus* fruit, UWBM 77433, loc. B4131 (Republic), x3.7. **50.** Vitaceous endocarp, UWBM 4770, loc. 2989 (Umtanum Creek), x13.8. **51.** *Vitis* endocarp, UWBM 56470-43, loc. B4101 (Yakima Canyon), x13.8. **52.** Burr-like fruit with wing, UWBM 96975, loc. B4131, x23. **53.** Capsule-like fruit, UWBM 56479-7, loc. B4101, x24. **54.** Capsule-like fruit, UWBM 56479-15, loc. B4101, x24. **55.** Capsule-like fruit (cross section), UWBM 56478-3, loc. B4101, x23.

Vitis endocarp (Yakima Canyon, Yakima County, UWBM 56470-43, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 5, Fig. 51)

Discussion—Vitaceous endocarps (fruit stones) are common in the Tertiary as mold-cast remains (Tiffney and Barghoorn, 1976) and are known from permineralized fossils of the Eocene Princeton Chert (Cevallos-Ferriz and Stockey, 1990) and the middle Miocene Umtanum Creek and Yakima Canyon (along with grape vines) sites. They also occur as compressions in the Eocene Swauk Formation and Coal Creek floras. *Vitis* leaves that superficially resemble maple leaves also occur in the middle Eocene McAbee flora of British Columbia.

Unknown Affinities

Burr-like fruit with wing (Republic, Ferry County, UWBM 96975, loc. B4131, middle Eocene Klondike Mountain Formation), Catherine Brown, collector (Plate 5, Fig. 52)

Capsule-like fruit (Yakima Canyon, Yakima County, UWBM 56479-7, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 5, Fig. 53)

Capsule-like fruit (Yakima Canyon, Yakima County, UWBM 56479-15, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 5, Fig. 54)

Capsule-like fruit (Yakima Canyon, Yakima County, UWBM 56478-3, loc. B4101, middle Miocene Ellensburg Formation), T. H. Tuggle and R. D. Foisy, collectors (Plate 5, Fig. 55)

Discussion—Tiny burr-like fruits, some with wings attached, are known only from the middle Eocene Republic flora. A small capsule-like fruit, found whole and broken into wedges, is known from the middle Miocene Yakima Canyon flora.

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Hydrangea Fossils from the Early Tertiary Chuckanut Formation

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Introduction

Flowers are among the rarest of fossils, and the diversity of floral remains in Washington deposits partly explains our state's reputation as a paleobotanical treasure house (Wehr, 1995; Wehr and Manchester, 1996; Pigg and Wehr, 2002). This floral record is expanded by the discovery of *Hydrangea* fossils in the early Tertiary Chuckanut Formation near Bellingham.

The first Chuckanut Formation *Hydrangea* specimen was an incomplete sterile flower found near Chuckanut Drive in Skagit County in 1987 by Burke Museum affiliate paleobotanist Don Hopkins. In 2000, Harold Crook collected a better specimen at this site (Fig. 1A) from strata near the base of the 6,000 m thick Chuckanut Formation. These beds are probably late Paleocene, as indicated by fossil pollen (Griggs, 1970; Reiswig, 1982) and fission track ages of detrital zircons (Johnson, 1984). A well-preserved *Hydrangea* leaf fossil (Fig. 1B) was found in 1996 in a utilities excavation near Bellingham in rocks of the Padden Member, the youngest stratigraphic unit in the Chuckanut Formation. This leaf fossil is probably late Eocene, but the age of the Padden Member has not been clearly established (Mustoe and Gannaway, 1997).

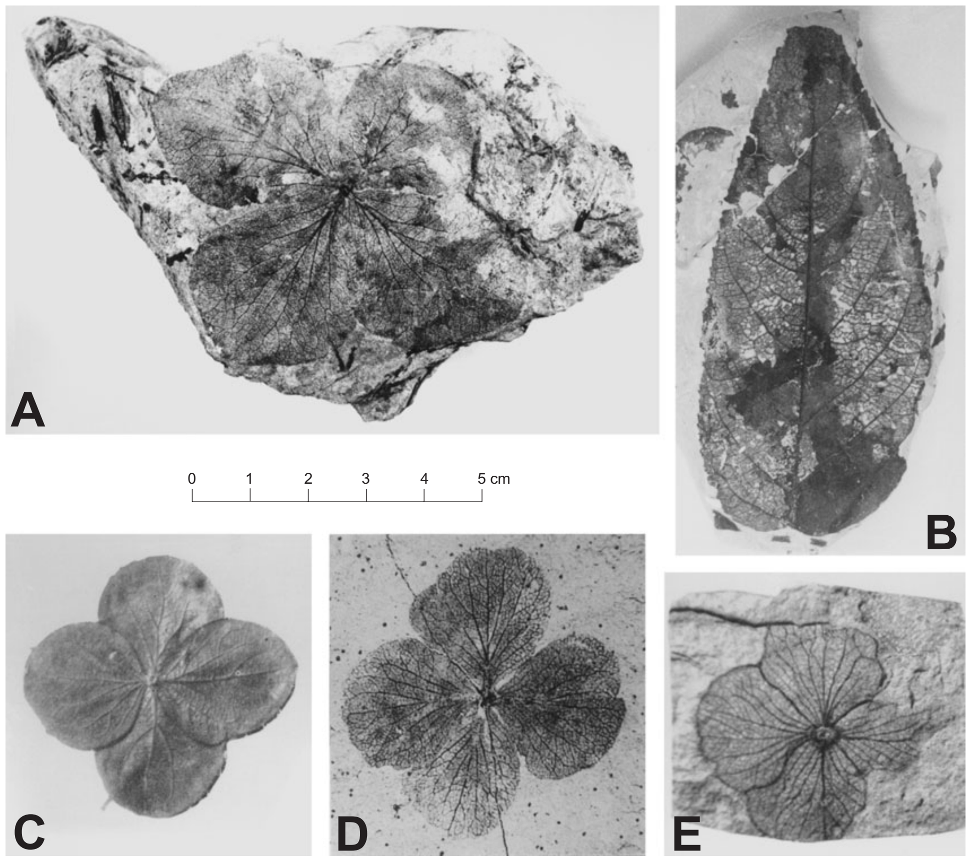

Figure 1. **A**, *Hydrangea* sterile floret, Chuckanut Formation, late Paleocene(?) Bellingham Bay Member, WWU-02-2-7, collected by Harold Crook from site WWU CD-5, Chuckanut Drive, Skagit County; **B**, *Hydrangea* leaf, Chuckanut Formation, late Eocene(?) Padden Member, not numbered, collected by Elaine Mustoe, site WWU-BK1, Bellingham; **C**, Sterile floret from extant *Hydrangea strigosa* Rehder, location and specimen number not recorded (Brown, 1937); **D**, *Hydrangea* sp., Eocene Clarno Formation, UF9962 (University of Florida), Gonser Road Clarno locality 238, central Oregon (Manchester, 1994); **E**, *Hydrangea bendirei* (Ward) Knowlton, Miocene Latah Formation, U.S. National Museum specimen 36979, from a railway cut in downtown Spokane (Knowlton, 1926).

Modern Hydrangea

A member of the Hydrangaceae family, the genus *Hydrangea* is comprised of 23 extant species of shrubs, small trees, and climbing plants (McClintock, 1957, 1973; Nevling, 1964; Lawson-Hill and Rothera, 1995). Although hydrangeas are prized by Pacific Northwest gardeners because of their showy clusters of blue or pink blossoms, none of the ornamental cultivars are native to the region. Two species, *Hydrangea arborescens* and *H. quercifolia* are endemic to the southeastern U.S., and 11 species of evergreen climbers grow in mountain areas of South and Central America. The main occurrence of *Hydrangea* is in temperate forests of eastern Asia—they can be found in Tibet, central and southern China, Japan, the Philippines, Taiwan, Java, and Sumatra.

Hydrangea flower heads (inflorescences) are composed of conspicuous four-petaled sterile florets (Fig. 1C) together with tiny fertile flowers. The latter may be grouped together near the center (Fig. 2) or distributed throughout the flower head. The sterile flowers may serve as an attractant and landing platform for pollinating insects (Lawson-Hill and Rothera, 1995). In many cultivated subspecies, the large, globular blossom clusters contain few, if any, fertile flowers. Sterile florets are well-represented in the fossil record, but some deposits preserve remains of the fertile flowers (Manchester, 1994).

Hydrangea foliage is either deciduous or evergreen, depending on the species. Most leaves are ovate or elliptic, arising from the stem in opposite pairs. Most species have serrate leaf margins, but a few species have smooth-edged ('entire') leaves. *Hydrangea quercifolia* of North America and *H. sikokiana* of Japan have pinnately lobed leaves. Leaf surfaces are glossy, smooth, matte, or hairy, according to the species.

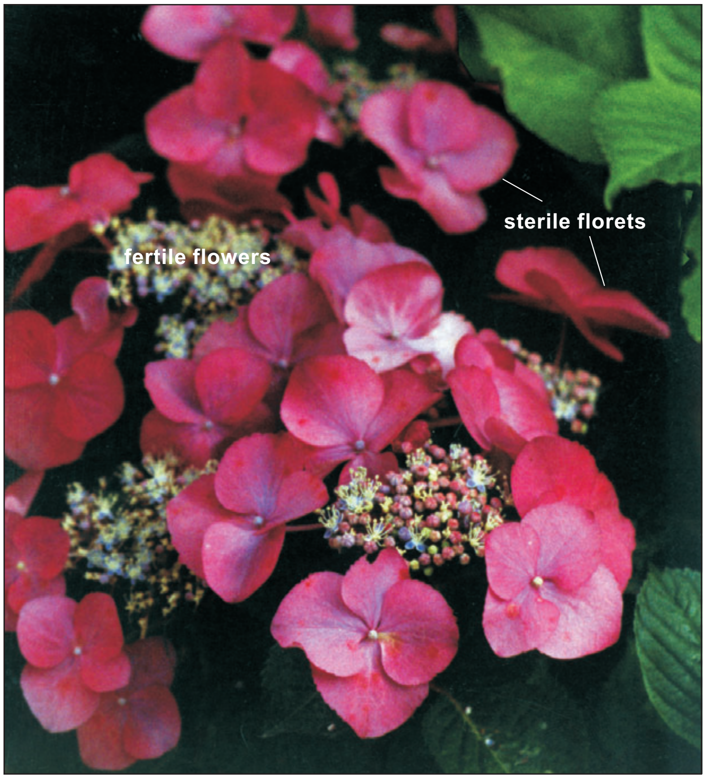

Figure 2. Flower head of an extant *Hydrangea macrophylla*, a lacecap variety, showing four-petaled sterile florets and small fertile flowers. *Photo courtesy of Jari Roloff.*

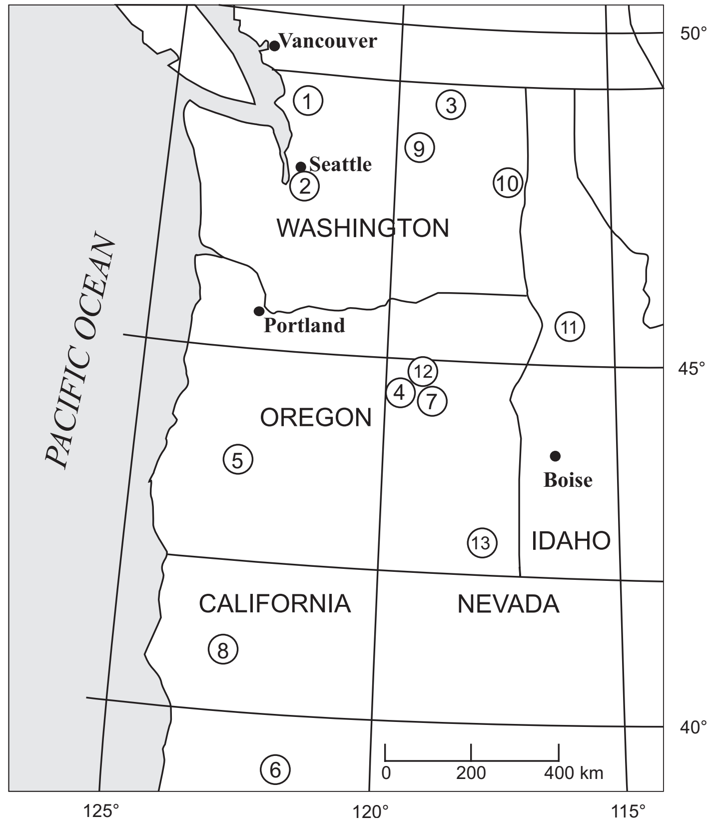

Figure 3. Occurrences of *Hydrangea* fossils in the Pacific Northwest. Eocene: 1, Chuckanut Formation; 2, Puget Group (Wehr, 1995); 3, Republic flora (Wehr and Hopkins, 1994); 4, Clarno Formation (Manchester, 1994); 5, Goshen flora (Chaney and Sanborn, 1933); 6, Chalk Bluffs flora (MacGinitie, 1941). Oligocene: 7, John Day Formation (Meyer and Manchester, 1997); 8, Weaverville flora (MacGinitie, 1937). Miocene: 9, Grand Coulee flora (Berry, 1931); 10, Latah Formation (Knowlton, 1926); 11, Whitebird flora (Berry, 1934); 12, Mascall Formation (Knowlton, 1902); 13, Trout Creek flora (MacGinitie, 1933; Arnold, 1937).

GEOLOGIC RANGE

Hydrangea fossils have previously been reported from paleofloras that range in age from Paleocene to Miocene (Fig. 3). Hollick (1925, 1936) described *Hydrangea* specimens from Paleocene and Eocene rocks of Alaska. Eocene *Hydrangea* leaves are preserved in the Goshen paleoflora of west central Oregon (Chaney and Sanborn, 1933) and the Chalk Bluffs and Weaverville paleofloras in northern California (MacGinitie, 1937, 1941). Wehr (1995) noted the presence of undescribed *Hydrangea* specimens from two localities in the Eocene Puget Group of western Washington. Flower imprints have been collected from the Eocene Clarno Formation (Fig. 1D) and Oligocene John Day Formation of Oregon (Manchester, 1994; Meyer and Manchester, 1997) and from Oligocene fossil beds at Florissant, Colorado (LaMotte, 1952). Miocene occurrences of fossilized *Hydrangea* flowers and foliage in Washington include the Latah Formation near Spokane (Fig. 1E; Knowlton, 1926) and at Grand Coulee (Berry, 1931). Other Miocene examples come from Whitebird, Idaho (Berry, 1934), and the Mascall and Trout Creek paleofloras of Oregon (Knowlton, 1902; MacGinitie, 1933; Arnold, 1937). *Hydrangea* fossils have also been reported from the Miocene Shantung flora of China (Hu and Chaney, 1940)

DISCUSSION

Hydrangea fossils occur in both subtropical and temperate paleofloras, demonstrating climatic tolerances that are much greater than that of extant hydrangeas. The geographic distribution of extant *Hydrangea* species (Fig. 4) is strikingly different from the currently known ranges of fossil species.

The presence of *Hydrangea* remains in both the oldest and youngest strata of the Chuckanut Formation provides evidence of the ability of the genus to adjust to climatic change during the early Tertiary. Mustoe and Gannaway (1997) used the Climate-Leaf Multivariate Program (CLAMP) method of Wolfe (1993) to study paleoclimate of the Chuckanut Formation. They calculated a mean annual temperature (MAT) of 15°C and a mean annual range of temperature (MART) of 10°C for the Bellingham Bay Member, which is at the base of the formation. These results are indicative of subtropical rain forest, as confirmed by the presence of abundant palm leaf fossils (Mustoe and Gannaway, 1995). The paleoclimate of the Padden Member, which is at the top of the formation, is quite different, with a MAT of 12°C and a MART of 18°C. The cooler climate and greater seasonal difference represent a warm temperate environment more like conditions where *Hydrangea* flourishes today. A similar trend is recorded in central Oregon, where *Hydrangea* fossils occur in both the Eocene subtropical Clarno paleoflora and in the warm temperate Bridge Creek paleoflora of the Oligocene John Day Formation. The same trend is true of other occurrences (Fig. 3), where *Hydrangea* fossils are present in Paleocene and Eocene subtropical paleofloras and in warm temperate paleofloras of later epochs. Our knowledge of the response of *Hydrangea* to paleoclimatic influences is limited by the fact that plant remains are likely to be preserved only under favorable geologic

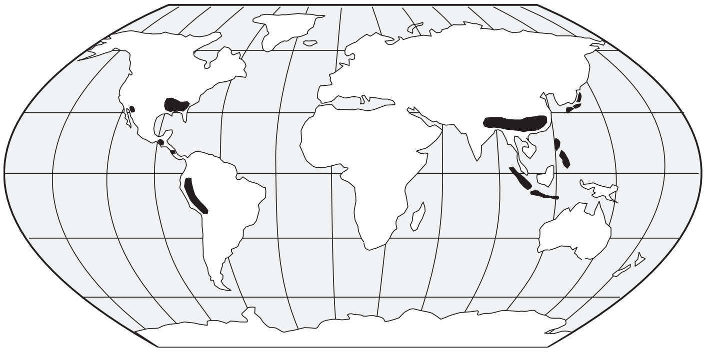

Figure 4. Geographic range of extant *Hydrangea*. Adapted from Lawson-Hill and Rothera, 1995.

conditions, and few regions have palefloras that span a broad age range.

Perhaps *Hydrangea* had broad climatic tolerances during the early Tertiary, contemporaneously inhabiting both subtropical and temperate environments. This interpretation is supported by the observation that two types of *Hydrangea* leaves have been found at middle Eocene fossil beds at Republic, Washington, a warm temperate paleoflora (Wolfe and Wehr, 1991; Wehr and Hopkins, 1994). Alternately, the genus may have initially evolved in subtropical forests and migrated to temperate environments during the Eocene. The latter interpretation is consistent with the observation that *Hydrangea* fossils have not been found in the middle Eocene temperate floras at McAbee and Princeton, British Columbia. More study is required to answer this question.

Meanwhile, *Hydrangea* fossils provide a reminder of the possible pitfalls of using floristic analysis to determine paleoclimate. Floristic analysis compares plant fossils to extant taxa that are inferred to be their nearest living relative. The climatic tolerances of the living plants are assumed to be similar to those of ancient ancestors. According to this hypothesis, *Hydrangea* fossils would be considered indicators of temperate climate. *Hydrangea* fossils are also a reminder of a second source of error: the search for a nearest living relative works only if the taxonomy of plant fossils can be correctly ascertained. *Hydrangea* leaves bear resemblances to those of other plant families, making identification problematic unless venation is preserved in detail. LaMotte (1952) lists instances where *Hydrangea* remains have been incorrectly assigned to the genera *Celastrus* (a tropical vine), *Fraxinus* (ash family), *Juglans* (walnut family), and *Rhus* (sumac family). The flowers are more distinctive, but in the past *Hydrangea* fossils have been misidentified as *Marsilia*, *Porana*, and *Euonymus* (genera from three families of tropical vines).

Both of these sources of error are avoided with vegetational analysis, which uses morphological features of dicotyledonous leaves as an indicator of climate. The CLAMP method (Wolfe, 1993, 1995) is the best-known example of this technique, but several alternative computational schemes have been proposed (Wing and Greenwood, 1993; Gregory and McIntosh, 1996; Herman and Spicer, 1997; Wilf, 1997). Each method has its supporters and detractors, and the reliability of each technique is a subject of debate. For example, calculations of the MAT for the Clarno paleoflora range from 14.3° to 18.8°C depending on the method that is used (Wiemann and others, 1998). Like the difficulty of forecasting next week's weather, the determination of ancient climates is presently a less-than-certain endeavor.

ACKNOWLEDGMENTS

Don Hopkins and Harold Crook deserve credit for reporting their discoveries of *Hydrangea* fossils. Steven Manchester (Florida Museum of Natural History) identified the fossil flower found by Crook, and Jack Wolfe (University of Arizona) recognized the identity of a leaf fossil collected several years earlier by Elaine Mustoe. Burke Museum Paleobotany Curator Wes Wehr deserves special mention for his many years of study of fossil flowers from the Pacific Northwest, providing a regional database that is essential for interpreting new specimens. The author thanks Wes Wehr and Kitty Reed for their careful manuscript reviews.

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BOOK REVIEW: Boom Towns and Relic Hunters of Northeastern Washington—A Comprehensive Guide to Ghost Towns in Six Historic Counties

by Jerry Smith
Elfin Cove Press, 2002, 136 p.
7 x 10-inch softcover, perfect bound, $19.95

Mr. Smith's book provides a good starting point for persons interested in exploration and relic hunting in our state's northern tier of ghost towns. The descriptions are very helpful for locating these sites, many of which are overgrown and on the verge of disappearing altogether. The before-and-after photos are particularly helpful. The sections devoted to the early history of Ruby City, Loup Loup, and Nighthawk contain interesting quotes from historic newspaper articles boosting the region's development. The chapter on metal-collecting ethics and equipment provides a nice tie-in for hobbyists using the book as a source for places to explore.

The author includes some in-text warnings concerning entering abandoned mines, however if the book is issued in subsequent revisions, I suggest including highlighted verbiage similar to that in *Discovering Washington's historic mines*[1]. My advice is to stay out of abandoned mines altogether unless accompanied by a guide familiar with the mine and its structural condition.

Errata:

Page 54. The Boundary Red Mountain Mining Co. stock certificate is not related to mining near the town of Boundary (Stevens Co.) described on same page. The mine is located at the 7000 foot elevation in northern Whatcom county about a mile south of the British Columbia border. The certificate is signed by W. E. Zoebel, listed as secretary of the company in the 1922 report to stockholders (DGER mine file).

Page 112. The Brown Bear mine at the summit of Hart's Pass is not operating during the summer, nor is the New Lite property of Western Gold located in the Barron basin. These properties had been idle for a considerable length of time prior to DGER field work there in the summer of 2001. Some placer miners have recreational sites under work on Slate Creek and its tributaries.

Fritz E. Wolff
Washington Division of Geology and Earth Resources

[1] Northwest Underground Explorations, 1997, Discovering Washington's historic mines; Volume 1—The west central Cascade mountains: Oso Publishing Company [Arlington, Wash.], 230 p.

EARTH CONNECTIONS

Resources For Teaching Earth Science

NATURAL RESOURCES AND YOUR HOLIDAY TREE

This holiday season, the last thing on our minds is the natural resources that bring pleasure to the season. The lights, decorations, greeting cards, and wrapping paper add to the excitement of the holidays. Have you ever thought about the raw materials that bring this image together? The majority of these raw materials were furnished by the mining and petroleum industries.

Although many of us drive to the forest to cut an evergreen tree, most of them are grown on tree farms. Like all crops, they are grown with fertilizers. About half of the world's production of sulfur and more than 90 percent of the phosphates and potash go into fertilizers, of which the sapling trees receive a share. Surface and ground water resources are also needed.

Strands of tiny lights add to the list of minerals that bring holiday cheer. The wires are made of copper; the insulation and wall plugs are formed by the combination of petrochemicals with pumice, limestone, marble, vermiculite, silica, feldspar, or trona. The glass bulbs contain feldspar, silica, clay, nepheline syenite, and trona; filaments in the bulbs are made of thin conductive strips of tungsten metal, which comes from the minerals scheelite and wolframite.

The glittering ornaments are made from a variety of materials. Plastic ornaments contain petrochemicals; ceramic and glass ornaments and candlesticks are made of ingredients similar to light bulbs and also contain borates and metals such as iron, copper, and lead. The ornament hangers and tree stands also are typically a metal alloy containing iron or aluminum. Colorful paints and glazes used to decorate the ornaments are based on petrochemicals, mica, or clay and are pigmented with ingredients such as lithium from spodumene, titanium from rutile, manganese from pyrolusite, and rare-earth elements from uncommon minerals. The wrapping papers and woods that the paints are applied to commonly contain clay as an additive or filler. And what about the resources that go into the gifts, or the electricity to light the icicle lights on the eaves?

TEACHER INSTRUCTIONS: Discuss or read the information above with students. For an introduction in classification, list the holiday items 1–12 on the board and have students organize the items into various categories that the items may contain: petrochemicals; metals; non-metals; wood (or containing carbon); etc.

QUIZ

Listed below are some items often associated with a holiday tree and some raw materials that are used to make these items. In the blanks write the letters of some of the raw materials used to make each item on the tree. Raw materials may be used more than once for the Holiday Tree Items. Refer to the Key for some possible answers.

HOLIDAY TREE ITEMS

1. Star ________________
2. Tree ________________
3. Ornament hangers ________________
4. Electrical wire ________________
5. Light bulbs ________________
6. Wire insulation ________________
7. Ceramic ornaments ________________
8. Plastic ornaments ________________
9. Electricity ________________
10. Glass ornaments ________________
11. Paint ________________
12. Tree stand ________________

RAW MATERIALS

a. sulfur
b. trona
c. lead
d. mica
e. petrochemicals, oil, natural gas
f. aluminum
g. potash
h. iron
i. silica
j. vermiculite
k. clays
l. silver
m. manganese
n. pumice
o. nepheline syenite
p. limestone
q. copper
r. phosphates
s. lithium
t. titanium
u. rare-earth elements
v. tungsten
w. wood
x. feldspar
y. coal
z. water

ESSENTIAL ACADEMIC LEARNING REQUIREMENTS

Science 1.1 The student will use properties to identify and categorize items into mineral components.

Science 1.2 The student will be able to recognize the components and structure of holiday items and the interconnections within and among them.

GRADE LEVELS

Grades 6–10

SUBJECTS

Earth science

CONCEPTS

Ordinary items are made from minerals

SKILLS

Analyzing, classifying and categorizing, interpreting

OBJECTIVES

Students will categorize products that contain particular minerals

TIME NEEDED

30–45 minutes

THE REAL OBJECT OF EDUCATION IS TO HAVE A MAN IN THE CONDITION OF CONTINUALLY ASKING QUESTIONS.

Bishop Creighton

Lesson created by
Dr. V. T. McClemore
and Doug Jones

Reprinted with permission from *Lite Geology*, Winter 1992, a publication of the New Mexico Bureau of Mines and Mineral Resources, http://geoinfo.nmt.edu/.

Earth Connections No. 7

KEY

1. Star: f, l, q
2. Tree: a, g, r, w, z
3. Ornament hangers: f, h
4. Electrical wire: q
5. Light bulbs: x, i, k, o, b, v
6. Wire insulation: e, n, p, w, j, x, b
7. Ceramic ornaments: x, i, k, o, b, h, q, c
8. Plastic ornaments: e
9. Electricity: e, y, z
10. Glass ornaments: x, i, o, b, h, q, c
11. Paint: e, d, k, s, t, m, u
12. Tree stand: h, f

EARTH CONNECTIONS GOES SOLO

Beginning with the next issue, Earth Connections will be online as a separate publication. A new issue will be available each March, June, September, and December.

WEB SITES FOR INFORMATION ABOUT MINERALS

The Mineral Gallery [http://mineral.galleries.com/minerals/byname.htm]—A growing collection of mineral descriptions, images, and specimens. Descriptions include searchable mineralogical data, plus other information of interest to students and rockhounds.

Mineralogy Database [http://webmineral.com/]—Contains information on more than 4,255 mineral species.

Mineral Information Institute [http://www.mii.org/]—Educational materials about mining and the role minerals play in our everyday lives, including free downloadable teachers' packets.

The Franklin Institute Online Hotlist, Earth Science Resources [http://www.fi.edu/tfi/hotlists/geology.html]—Links to web pages on geologic topics, including rocks and minerals.

Washington Geology [http://www.wa.gov/dnr/htdocs/ger/washgeol.htm]—The first issue of each year is the "mining issue," discussing the mining industry in Washington during the previous year.

Women in Mining [http://www.womeninmining.org/]—Lessons, games, and activities to teach kids about minerals and mining.

National Mining Association [http://www.nma.org/about_us/publications/pub_minerals_uses.asp]—*40 Common Minerals and their Uses* is available as a PDF file online. Several other booklets are available free or for a small fee.

Northwest Mining Association [http://www.nwma.org/education.asp]—Information on the uses and value of minerals and mining to our society and the industry's commitment to environmental responsibility. *Mighty Minerals* is a teaching unit for the 4th grade classroom focusing on some of the basic characteristics of metallic and nonmetallic minerals. Lesson plans focus on specific facts, applications, and current issues related to each mineral and can be downloaded for classroom use.

National Science Teachers Association [http://www.nsta.org/conventions/]—At area conventions of the National Science Teachers Association, the Society for Mining, Metallurgy, and Exploration, in cooperation with other organizations involved in the minerals industry, hosts exhibits that distribute free mineral samples and classroom teaching aids to approximately 1500 teachers at each convention.

USGS Mineral Surveys [http://minerals.usgs.gov/minerals/]—Production information and uses of each mineral mined in the U.S.—statistics on the worldwide supply, demand, and flow of minerals and materials essential to the U.S. economy, national security, and the protection of the environment. (Adult level: Teachers will need to show students the charts that indicate the uses to which each mineral is made.)

MORE RESOURCES FOR TEACHERS

GEOLOGY OF NATIONAL PARKS

National Parks are not only beautiful places to view wildlife and magnificent panoramas, they also contain some of the most spectacular geologic features in our country. The National Park Service has developed a website where teachers can explore the geology of several national parks where geologic features are especially well developed. Go to http://www2.nature.nps.gov/grd/edu/.

The website features a variety of resources. For example, one link is devoted to videos of parks, such as Mount Rainier, Grand Canyon, and Yellowstone. Another link contains a list and descriptions of recent books on the geology of national parks. Elsewhere, teachers can find PowerPoint presentations describing various geologic concepts and curricula on paleontology and the evolution of life on Earth.

Many exercises are rated by grade level; teachers can quickly determine if the curriculum is appropriate for their students. Also, there are some hands-on activities that illustrate geologic processes clearly and cheaply.

from NDGS Newsletter, vol. 29, no. 1, p. 19

BECOME A VIRTUAL SEISMOLOGIST

Whether you are a student, or someone who feels seismology-deprived, you will want to check out California State University's virtual courseware "Earthquake" at http://www.sciencecourseware.com/eec/Earthquake/. Funded by the National Science Foundation (NSF), "Earthquake" features virtual labs on using seismic waves to locate an earthquake's epicenter and determine its Richter magnitude. You will use maps and seismograms to record observations in a scientific journal. At the end, you take a quiz, and if you successfully complete it, you will receive a Certificate of Completion as a Virtual Seismologist. The virtual experience is a fun and educational way to pass an afternoon.

from Geotimes, August 2002, p. 38

FREE GUIDES TO GEOSCIENCE CAREERS/EDUCATION

The Guide to Geoscience Careers and Employers is available online at http://guide.agiweb.org/employer/index.html. The Guide is an up-to-date publication containing information on all aspects of geoscience employment opportunities as well as listings of major geoscience employers.

The Guide to Geoscience Departments can be found at http://guide.agiweb.org/ggd/index.html. It presents detailed information on almost 200 geoscience departments in the U.S. and Canada, both public and private.

ATLAS OF EARTH MYSTERIES

Edited by Philip Whitfield, this Rand McNally publication is a "vivid reminder of natural powers in all their amazing diversity….proffers new theories to explain the age-old enigmas….reveals that many of the awkward facts, unidentifiable happenings, and incomprehensible events that haunt our daily lives and form a web of unexplained phenomenon are peculiar to our planet. This fascinating, beautifully illustrated compendium focuses on the most bizarre and wondrous mysteries of planet Earth. Each is admirably furnished with an in-depth, broad-based and multidisciplined scrutiny involving geography, geology, meteorology, biology, and other natural sciences." [quotes from book sleeve]

GUIDE TO NISQUALLY NATIONAL WILDLIFE REFUGE

The Nisqually National Wildlife Refuge (Olympia, Wash.) has a new *Educator's Guide to Nisqually National Wildlife Refuge* available for loan to teachers. Contact Jennifer Taylor, environmental education coordinator, at (360) 753-9467.

PROJECT ASTRO/SEATTLE

Project ASTRO pairs grade 3–12 teachers with volunteer amateur and professional astronomers and earth scientists with the goal of building long-lasting partnerships to improve science education in schools. Over the course of the school year, each scientist visits his/her class at least five times, developing a relationship with the students, assisting the teacher, and/or leading astronomy/earth science activities. These activities may include hands-on science, question-and-answer sessions, evening star parties for students and their families, or large class projects such as building a telescope or a school sundial. There are currently 59 partnerships (involving approximately 2650 students) in schools throughout the Puget Sound region.

Although based at the University of Washington, Project ASTRO is substantially aided by its consortium, with representatives from the Pacific Science Center, the Museum of Flight, the UW Astronomy Department, the Seattle Astronomical Society, the Washington State NASA Space Grant Office, local school districts, community colleges, and teachers.

Project ASTRO was founded in 1993 by the Astronomical Society of the Pacific (ASP) in San Francisco with a grant from the National Science Foundation (NSF). In 1997, UW Astronomy Professor Woodruff Sullivan received a NSF grant to start Project ASTRO in Seattle. There are ten Project ASTRO sites across the country.

Teacher and scientist partners attend a mandatory two-day professional development training workshop, receive a 700-page curriculum guide and classroom resource materials for hands-on activities, develop strategies for working together in and out of the classroom, network with fellow teachers/astronomers, and obtain information about other learning opportunities in the region.

Project ASTRO also hosts educational events throughout the school year, including Museum of Flight workshops, Pacific Science Center events, University of Washington events, Astronomical Society Star Parties, and a spring networking and evaluation workshop. Additional project support includes the ASTROGRAM newsletter (quarterly) and an e-mail discussion listserv (subscribed newsgroup).

Applications for the 2003/04 school year are available starting February 28. Applications are due May 1, 2003. Applicants will be notified of selection by about June 1, 2003. (Selection of partners is based on having a partner astronomer available in your region and teacher enthusiasm for hands-on science.) For more information, go to the UW website at http://www.astro.washington.edu/projAstroBio/.

To request an application, contact Linda Khandro at lindak@astro.washington.edu or (206) 543-9541. Specify if you would like a teacher or science partner application.

For general information on Project Astro nationwide, visit their website at http://www.astrosociety.org/.

NASA EDUCATOR RESOURCE CENTER

Educators will find various materials to support K–12 science and mathematics teaching at the NASA Educator Resource Center in Johnson Hall, Room 401, on the University of Washington campus in Seattle. These include curriculum packets, education briefs, posters, lithographs, bookmarks, videotapes, slides, and books. Some materials are free (curriculum packets, poster, lithographs, bookmarks) while others can be borrowed (books, slides) for a one-month period or copied (videotapes). Videotape copies are $5 each. Free materials that are mailed will be charged a fee for postage only. Educators are encouraged to visit the ERC personally to see what is available. (The center is open Monday–Friday, 9:00 am–5:00 pm.) If that is not possible, contact Dr. Julie Lutz (206) 543-0214 or e-mail to nasaerc@u.washington.edu to discuss specific needs.

EARTH SCIENCE WEEK

Although Earth Science week (October 13–19, 2002) has come and gone, the website http://www.earthsciweek.org/ still has plenty of geoscience activities and free materials.

The Division of Geology and Earth Resources Earth Science Week website is http://www.wa.gov/dnr/htdocs/ger/esweek/index.html.

AMERICAN GEOLOGICAL INSTITUTE

AGI Professional Development includes curriculum leadership institutes, teacher enhancement workshops, and web-based teacher enhancement. Curriculum materials are available for all grade levels. Summer workshops are held in the eastern U.S. See http://www.agiweb.org for member societies and general information, and for earth science resources, see http://www.earthscienceworld.org/.

EARTH SYSTEM SCIENCE EDUCATION ALLIANCE

ESSEA has created a national professional development program aimed at improving the knowledge, skills, and resources of earth systems science educators. This professional development program offers state-of-the-art, online courses to promote understanding of Earth Systems Science, to encourage communication and cooperation among teachers, and to facilitate the use of exceptional classroom materials. Earn graduate or continuing-education credit. The three available ESS courses (for teachers of grades K–4, 5–8, 9–12) use an innovative instructional design model. Delivered over the Internet, they feature participant-centered, knowledge-building virtual communities, the optimal method for teaching and learning. For more information, go to http://www.tsgc.utexas.edu/lists/teachers/links/ii/42/link_01.html. ■

DIVISION PUBLICATIONS

Print Publications

Tsunami Inundation Map of the Port Angeles, Washington, Area, Open File Report 2002-1, by Timothy J. Walsh, Edward P. Myers III, and Antonio M. Baptista, 48″ x 36″ color plate, scale 1:24,000. Paper copy $6.94 + .56 tax (Wash. residents only) = $7.50; CD $.93 + .07 tax (Wash. residents only) = $1.00. [Also on the web at http://www.wa.gov/dnr/htdocs/ger/]

Tsunami Inundation Map of the Port Townsend, Washington, Area, Open File Report 2002-2, by Timothy J. Walsh, Edward P. Myers III, and Antonio M. Baptista, 38″ x 36″ color plate, scale 1:24,000. Paper copy $6.94 + .56 tax (Wash. residents only) = $7.50; CD $.93 + .07 tax (Wash. residents only) = $1.00. [Also on the web at http://www.wa.gov/dnr/htdocs/ger/]

Geologic Map of the Utsalady and Conway 7.5-minute Quadrangles, Skagit, Snohomish, and Island Counties, Washington, Open File Report 2002-5, by Joe D. Dragovich, Lea A. Gilbertson, David K. Norman, Garth Anderson, and Gary T. Petro, 34 p. text, 2 color plates, 28″ x 48″ and 36″ x 40″. Paper copy $16.20 + 1.30 tax (Wash. residents only) = $17.50; CD $.93 + .07 tax (Wash. residents only) = $1.00. [Also on the web at http://www.wa.gov/dnr/htdocs/ger/]

Geologic Map of the Fortson 7.5-minute Quadrangle, Skagit and Snohomish Counties, Washington, Open File Report 2002-6, by Joe D. Dragovich, Lea A. Gilbertson, William S. Lingley, Jr., Michael Polenz, and Jennifer Glenn, 46″ x 36″ color plate. Paper copy $6.94 + .56 tax (Wash. residents only) = $7.50; CD $.93 + .07 tax (Wash. residents only) = $1.00. [Also on the web at http://www.wa.gov/dnr/htdocs/ger/]

Geologic Map of the Darrington 7.5-minute Quadrangle, Skagit and Snohomish Counties, Washington, Open File Report 2002-7, by Joe D. Dragovich, Lea A. Gilbertson, William S. Lingley, Jr., Michael Polenz, and Jennifer Glenn, 46″ x 36″ color plate. Paper copy $6.94 + .56 tax (Wash. residents only) = $7.50; CD $.93 + .07 tax (Wash. residents only) = $1.00. [Also on the web at http://www.wa.gov/dnr/htdocs/ger/]

Reconnaissance Investigation of Sand, Gravel, and Quarried Bedrock Resources in the Shelton 1:100,000 Quadrangle, Washington, Information Circular 97, by Andrew B. Dunn, Gordon Adams, William S. Lingley, Jr., Jeffrey S. Loen, and Anthony L. Pittelkau, 54 p., 5 appendices, 1 figure, 5 tables, and 1 plate, scale 1:100,000. $8.80 + .70 tax (Wash. residents only) = $9.50.

Liquefaction Susceptibility of the Greater Eastside Area, King County, Washington, Geologic Map GM-48 (released out of sequence), by Stephen P. Palmer, Brian D. Evans, and Henry W. Schasse, 14 p. text, 1 color plate, scale 1:36,000. This map provides land-use planners, emergency-response personnel, engineering consultants, developers, insurance providers, and private citizens with a relative assessment of the likelihood of soil liquefaction during an earthquake. $2.78 + .22 tax (Wash. residents only) = $3.00.

Geologic Map of Washington—Northwest Quadrant, Geologic Map GM-50, by Joe D. Dragovich, Robert L. Logan, Henry W. Schasse, Timothy J. Walsh, William S. Lingley, Jr., David K. Norman, Wendy J. Gerstel, Thomas J. Lapen, J. Eric Schuster, and Karen D. Meyers, 3 plates (Plate 1, scale 1:250,000), 76 p. text, 14 figures, 2 tables. $9.26 + .74 tax (Wash. residents only) = $10.00 per copy ($11.11 + .89 = $12.00 for a flat map in a tube).

Roadside Geology of Mount St. Helens National Volcanic Monument and Vicinity, Information Circular 88 [revised edition 2002], by Patrick T. Pringle, 132 p., 70 black and white figures, coated cover. $3.24 + .26 tax (Wash. residents only) = $3.50.

CD Only Publications

Digital Geologic Maps of the 1:100,000 Quadrangles of Washington, Digital Report 2, October 2002 edition. Coverages are in ArcInfo 8.0.2 format. Coverages for each individual 1:100,000 quadrangle in the state are included. Metadata include an Excel spreadsheet that briefly describes the age, lithology, and formal or informal name of each geologic unit by unit symbol and 1:100,000 quadrangle, a second Excel spreadsheet that lists which ArcInfo coverages are included for each 1:100,000 quadrangle, and a Word document that describes the data (sources, data structure, data item definitions, etc.). New to this edition: Statewide coverages are included for the first time. Data structures have been corrected as necessary so that all individual quadrangle coverages can be appended (joined together) successfully. Superfluous files have been removed. Errors have been corrected when they have been brought to our attention.

On-Line Only Publications

Inactive and Abandoned Mine Lands Inventory—Azurite Mine, Whatcom County, Washington, Open File Report 2002-3, by Fritz E. Wolff, Donald T. McKay, Jr., and David K. Norman, 8 p. [On the web at http://www.wa.gov/dnr/htdocs/ger/iaml/02-3/]

Inactive and Abandoned Mine Lands Inventory—Sunset Mine, Snohomish County, Washington, Open File Report 2002-4, by Fritz E. Wolff, Donald T. McKay, Jr., and David K. Norman, 9 p. [On the web at http://www.wa.gov/dnr/htdocs/ger/iaml/02-4/]

New Prices in Effect

To cover our actual costs for printing, we have increased the prices of some publications. This was prompted by an increase in the cost of reproducing large-format plates (now run on the plotter instead of the ozalid) and affects mainly open file reports. These prices supersede those listed in the April 2001 version of our publications list. Contact our office for details (see p. 2).

Please Add Shipping and Handling

To cover our shipping costs, we have switched from the former flat fee of $1.00 to the cost schedule shown at right. For each additional $20.00 in publication costs over $110.00, add $1.00 in postage and handling. For more information, go to http://www.wa.gov/dnr/htdocs/ger/pubcost.htm.

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$70.01–$90.00	$8.50
$90.01–$110.00	$9.50

NSF GRANT ESTABLISHES MICROBIAL OBSERVATORY AT SOAP LAKE

The National Science Foundation recently announced the award of an $840,000 grant to establish a multidisciplinary microbial observatory at Soap Lake. The award provides funding for three years to support research directed by Holly Pinkart (Central Washington Univ.), Melanie Mormile (Univ. of Missouri-Rolla), and Brent Peyton (Washington State Univ.).

The goals of the project are to characterize the microbial communities that inhabit Soap Lake, and determine how they affect, and are affected by, the lake's geochemistry. The observatory will likely lead to discovery of novel microorganisms useful in industry and biotechnology. Additionally, the project will allow for the significant involvement of undergraduate students, and could serve as a model for the integration of research into undergraduate education. For more information, see http://www.fastlane.nsf.gov/servlet/showaward?award=0132158.

from Ice Age Floods Institute Newsletter, Catch-up edition, Fall 2001–Summer 2002